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EVOLUTION OF SPHINCTER MUSCLE PRESERVATION AND RE-ESTABLISHMENT OF CONTINUITY IN THE OPERATIVE TREATMENT OF RECTAL AND SIGMOIDAL CANCER

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A REVIEW of the literature in native and foreign tongues discloses that much effort has been made to eliminate abdominal colostomy in the treatment of rectal and low sigmoidal cancer.

In 1833, Reybard of Lyons removed a cancerous growth from the sigmoid flexure of a man aged 28 years. The tumor was excised with 3 inches of intestine and the two ends stitched together, replaced within the abdomen, and the wound closed. Although the patient lived 10 months, Reybard's method was severely criticized by the Paris Academy of Medicine. Ninety-nine years later, Dieffenbach left the pararectal musculature intact following resection of the rectum by suturing the proximal to the distal segment. The Lisfranc operation, consisting of a restricted excision of the rectum and introduced in 1826, had fallen into disuse, but was revived and modified by Verneuil in 1873 to preserve the sphincter muscles and offer a less restricted operative field. Two years later, Kocher introduced his method of excision in which the rectum was removed as a closed tube. The perianal skin and external sphincter were retained and the sigmoid attached thereto. Gersuny in 1878 excised the cancerous rectum and made a three-quarter twist of the bowel before attaching it to the anal skin. After amputation of the rectum, Witzel sutured the proximal end of the bowel to the skin through slits in the pyramidalis and gluteus maximus muscles; Rydygier employed only the gluteus. Perron, too, maintained continence by approximating the ends of the gut in a manner not unlike that advocated by Kocher. New impetus was given the surgical treatment of rectal cancer by Kraske, who in 1885 offered a method for growths in the lower, mid, and upper thirds of the rectum. After excision of the coccyx and a segment of the sacrum, the rectum was resected and continuity established by circular suture. Various modifications were cited in his subsequent contributions. Shortly thereafter, von Heineke proposed an osteointegumental flap to support the sphincter and levator musculature. Invagination of the upper rectal segments through the lower end, following excision, was performed by Hochenegg, to which the name "pull-through" or *Duerchzug* method was applied. In an effort to avert the formation of a fecal fistula, he removed the modified skin from the anal canal prior to the process of invagination.

In 1888, Allingham of England, devised a method which subsequently attained wide

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recognition. An incision was made in the midline from the tip of the coccyx to, but not including, the posterior wall of the rectum. The external sphincter was divided anteriorly, then a circular incision was carried around the bowel between the internal and external sphincters so as to leave the latter muscle attached to the skin of the anus. The levator ani muscles were divided close to the bowel, and the rectum was isolated by dissecting close to its wall. The pelvic peritoneum was not opened, but the bowel was divided about an inch above the growth. Under the heading of abdominoanal excision, Maunsell, in 1892, described a method which was later improved upon by Weir, Ball, and Aldrich-Blake. Mobilization of the rectum and sigmoid was effected through an abdominal incision, and the inferior mesenteric artery was ligated below the origin of the lower sigmoidal branch. A ligature was tied around the bowel at a point considered most suitable for joining the anus. The freely movable bowel was pushed into the pelvis, and a peritoneal diaphragm was reconstructed. After closure of the abdominal wound, an incision was carried around the anus to the coccyx, the sphincter and levator muscles being separated in the midline. The diseased bowel was pulled through the pelvic floor and excised. The end of the proximal segment was then fixed to the levator ani and sphincter by several catgut sutures passing through the appendices epiploicae and the longitudinal muscle band.

In America, J. B. Murphy presented his method of rapid anastomosis by the aid of a metal button. He, as well as others, notably Marcy, Mayo, Hartmann, and McBurney, employed it in low sigmoidal growths. Shortly thereafter, Giordiana performed an abdominoperineal excision without preliminary abdominal colostomy. In 1897, Quenu followed Czerny's example of rectal extirpation, but preserved the sphincter muscles. Here, a circular incision was made through the skin surrounding the anus with dissection upward inside the sphincter muscle for a distance of one-quarter inch. A strong ligature was tied around the cylinder thus formed to serve as traction. The anus was cauterized and the external sphincter incised anteriorly and posteriorly in the midline, the latter being carried to the coccyx, which was usually removed. The rectum was dissected free up to the peritoneum, which was opened to permit descent of the bowel. Following closure of the peritoneum, the rectum was amputated above the growth, and the proximal end sutured to the skin. The procedure was well received, and in 1903 was modified by Tuttle, and adopted by such eminent surgeons as Abby and C. H. Mayo who employed it in preference to the sacral method. With the turn of the century, Cripps advocated a procedure not unlike that of Allingham, whereby the main fibers of the external sphincter were preserved.

Archibald (4) of Montreal, in 1905, performed an unusual type of operation which was reported 3 years later. He gives credit to Kuemmell, De Quervain, and Treves for having performed it previously. The patient in question had been given an inguinal colostomy for tuberculous proctitis; then because of narrowing of its orifice, he mobilized and excised the rectum and sigmoid and transplanted the descending colon into the anus to preserve the sphincter function. The patient died of shock, but postmortem examination disclosed no impairment of circulation to the transplanted bowel. Thirty years later, Archibald (5) mentions that he discontinued the procedure because of circulatory impairment to the bowel. Only the one case was cited, however.

The year 1908 altered the temper of the development of methods toward re-establishment of bowel continuity and sphincter muscle preservation by the contribution of Miles. Based on the anatomic studies by Poirier, Cuneo, and Delamere, he contended that cancer extends in three directions, known as the zones of spread: upward, lateral, and downward—and demonstrated conclusively that the incidence of recurrence could be greatly diminished by wide extirpation of the cancerous rectum and contiguous glandbearing tissues. His method of abdominoperineal excision was immediately accepted and even today remains the most popular procedure. The same year, another Londoner, Lockhart-Mummery (68) excised the pelvic sigmoid and established continuity over a glass or rubber tube by end-to-end suture. He credits Morison for the pro-

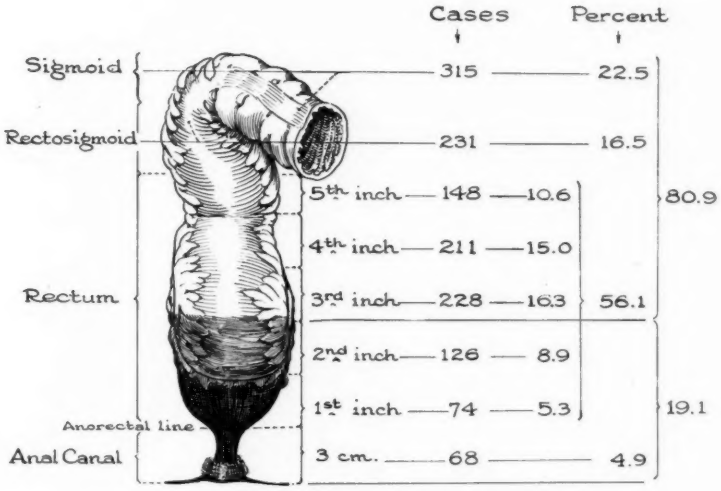

Fig. 1. The distribution of cancer in 1401 cases.

cedure. Additional reports of the use of this technique were made by Balfour (18, 19). Kuettner, in 1910, reported a three stage abdominosacral maneuver; while Morestin, in 1918, reversed Hochenegg's procedure by removing the lining of the distal segment and splicing the bowel by pulling it up over the distal segment, where it is sutured. A few years later, Gant, in an effort to preserve the sphincter musculature, excised the anal skin, split the external sphincter anteriorly and posteriorly, and, after excising the growth, sutured the proximal end of the bowel to the skin; thereafter, the anterior and posterior incisions and divided sphincters were approximated with catgut. Lockhart-Mummery(66), in 1923, described an alternate method of abdominoperineal excision to preserve sphincter function by bringing the stump of the sigmoid down and stitching it to the anus. A similar method of sphincter muscle preservation was also designed by Perthes.

W. Wayne Babcock (8) devised a method of "proctosigmoidectomy" without colostomy, and in 1932 described his experiences in a series of 30 cases in which the operative mortality was 10 per cent. Applicable in all types of removable cancer below the level of the midsigmoid, this method, aside from the elimination of a colostomy, offered several advantages; namely, the radicability of the excision is not compromised, the formation of a pelvic diaphragm is omitted, the delivery of the bowel through the perineal wound is made by traction on healthy rather than on diseased tissue, and an adequate perineal anus (anal sigmoidostomy) is formed in a single stage operation. Modifications and additional data are available in his subsequent contributions.

The next decade brought forth various modifications of procedures already outlined. Cuneo, Seneque, and Zagdoun (29) modified their original method (28) by resection of the rectum through one ischiorectal fossa without sacrificing the hemorrhoidal nerves on the opposite side. Grey Turner performed an end-to-end anastomosis within the abdomen for sigmoidal lesions, and a "pull-through" abdominoanal procedure preserving the sphincter muscles for rectal growths; while Devine (32, 33), describes a method of rectosigmoidal resection with end-to-end anastomosis after a period of "defunctioning"; when the rectum must be extirpated, he may do a telescopic anastomosis, not unlike that presented by Lockhart-Mummery and Balfour. Lahey, an advocate of permanent colostomy and stage operations, cites 3 cases of delayed restoration; the growth was resected, a colostomy formed, and the rectal stump closed. Three

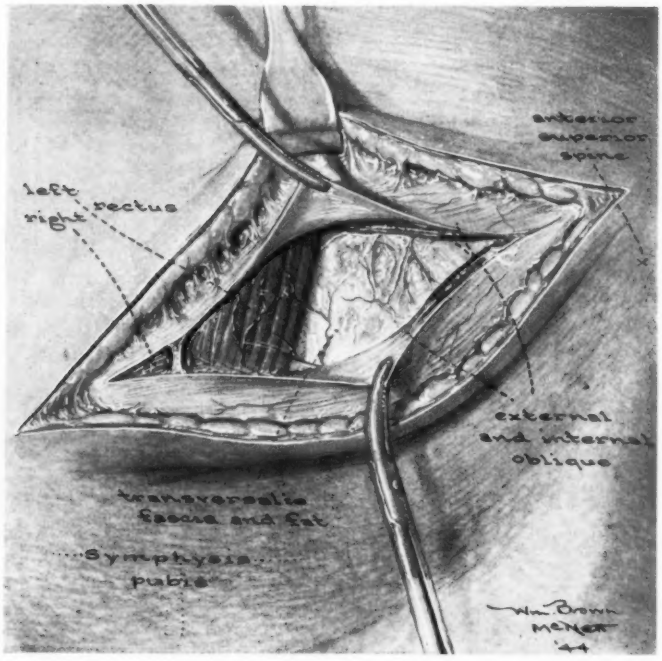

Fig. 2. Diagonal incision in the left lower quadrant of abdomen parallel to Poupart's ligament.

to 5 years later, the bowel was mobilized as far as the splenic flexure and anastomosed to the rectal stump. To avoid an artificial abdominal stoma, Jerome Lynch (69) advocated amputation by the perineal route, in which the bowel is divided at the level of the peritoneal floor with no attempt at approximation.

Independently, under the title of abdominoperineal-sacral or anal excision, Berg, Pannett, Arnold (6), Pratt, Pack (80), Bergeret and Livory, Wilensky, and Wangensteen (98) describe their technique in one, two, or three stages with preservation of the sphincter musculature; while Horsley, Wood and Wilkie, Babcock (9), Fallis, Arnold and Shea (7), Wangensteen (98), Dixon, Dunphy, as well as Zinninger and Hoxworth offer contributions to the literature in which the rectum, rectosigmoid, and lower sigmoid are mobilized and resected with immediate re-establishment of continuity by open or aseptic end-to-end anastomosis.

By the foregoing, it is obvious that remarkable progress has been made toward eliminating a colostomy, either by preservation of the sphincter musculature or by re-establishment of continuity of the resected lower sigmoid, rectosigmoid, or upper rectum.

"Why should a colostomy be avoided?" is a logical question. How many times, after stating that an artificial opening on the abdomen is imperative, have we heard patients say, "Doctor, I would rather die than have a colostomy!" One is prone to wonder how many patients have died needlessly by refusing such an operation when radical surgery by other means was not made available to them. Surely many 3, 5, and 10 year cures could have been effected. Too often, colostomized patients are socially ostracized, a train of psychoneurotic manifestations may be suffered even to the point of suicide, marriage may be interfered with, and many are unfit for employment and thereby refused a means of liveli-

Fig. 3. After small intestines are displaced from operative field by means of packs, mobilization of sigmoid is begun. Left lateral peritoneal leaf has been incised to expose ureter. This incision is joined behind base of bladder by an incision in the mesial leaf of the peritoneum.

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Fig. 4. The inferior mesenteric vessels are ligated at level of common iliac bifurcation. Thus, virtually all sigmoidal vessels and their arcades are preserved, and sufficient viable bowel is assured.

hood. Babcock and the writer have many case histories in their respective files which serve to substantiate this. To date, he and I have transplanted the colostomy to the perineum, or anastomosed the colonic to the rectal stoma, with or without resection, in 51 instances with but 1 death—mortality 1.9 per cent.

In this group were two physicians and one dentist who were handicapped in the performance of their daily tasks, several domestics were compelled to seek positions elsewhere, a child developed a marked inferiority complex because her classmates teased concerning her abdominal opening, a woman was unable to hold her position in a bank, an assistant superintendent of a large Philadelphia hospital after 22 years of service was about to be relieved of his position until transfer of the colostomy was effected, an evangelist was unable to carry out his duties, and in 3, marriage was postponed until transference of the colostomy was made. These patients attest that they are more pleased, that the discharge of offensive gas is less evident, that the perineal opening is more convenient and easier to care for, and that the evacuations are more satisfactory and less frequent. Should not the opinions of persons afflicted with this dreaded disease, who have been subjected to a colostomy life and now possess a perineal anus (anal sigmoidostomy), serve as an index as to its efficacy? As Horsley said a few years ago, "Something more than mere existence should be included in the objectives of surgery . . . if the patient can be made more comfortable and life is made to seem more worthwhile after a procedure that offers about equal chances of cure of the cancer as other operations, it is obvious that this technique should be adopted."

The main objective in the treatment of cancer is, of course, complete eradication of the disease. Even though a colostomy is considered by many sacrosanct, is it essential and does preservation of the sphincter musculature compromise the radicability of the operation? It has become apparent that the views held by Miles (75), as to the lateral and especially the inferior zones of spread necessitate some modification. The painstaking pathologicoanatomic studies by Westhues, in 1934, showed that cancerous connective tissue and lymph-node metastases are situated at the level of the carcinoma or above it. Gabriel, Dukes, and Bussey (42) concurred in these findings and remarked, "Lateral or downward lymphatic spread is only found in a late stage of the disease when the hemorrhoidal lymphatics are blocked by metastases." Coller found no evidence of retrograde metastasis to nodes situated 5 centimeters below the primary site, although Gilchrist and David (45, 46) noted 4 such instances. Coller further observed no metastases along the lateral zone of spread where the inferior border of the lesion was 3 centimeters or more above the mucocutaneous junction (anorectal line). It may be assumed, therefore, that the inferior zone of spread is relatively unimportant, whereupon the sphincter musculature may be preserved, provided the lower border of the growth is 3 centimeters or more above the anorectal line (6 centimeters above the anal margin). Based on an experience of over 1,000 operations, Lynch (70), in referring to the work of Dukes, remarks, "It permits one to discard entirely such radical and unnecessary operations as that popularized by Miles."

It seems appropriate to inquire, "If the sphincters may be preserved in all cancers situated above the six centimeter level, in what proportion of cases do these occur?" A few years ago, the author (12, 13) reviewed a series of 1,995 cases of malignancy involving the anus, rectum, and sigmoid colon, in which the distribution was accurately noted in 1,401 instances as shown in Figure 1.

It is evident that only 10.2 per cent of lesions (4.9 and 5.3) occur within the distal 5.5 centimeters of the bowel (above the anal margin), and 19.1 per cent (4.9, 5.3, and 8.9) within the distal 8 centimeters. It may be deduced, therefrom, that at least 80.9 per cent of cancers or those above this level may be removed without sacrifice of the sphincter muscles. Mandl (71), in 1922, observed that of 461 operations for cancer of the rectum, the sphincters were preserved in 227 cases. He concluded, "Wherever possible, in situations where the tumor is at a sufficient distance from the sphincters, these should be pre-

TABLE I.—RESECTED WITH COLOSTOMY

Name	Year reported	No. cases resected	Resectability rate %	Mortality rate %	Survivals %	Survivals Years
Hayden and Shedden (52)	1930	63	21	6.3	22	5 or more
Rankin (90)	1933	300	50–68	7.7	38	5 or more
Lockhart-Mummery (67)	1934	340		8.0	52	5
Jones, T. (56, 57)	1935 1936	127 151	79	11.0	52 62 70	5 3 to 5 1 to 3
Raiford (89)	1935	117	32.4 63.5	22.2	23.2 36	5 5
Abel (1)	1935				69.3	5
Jones, D. F. (55)	1936	463		17.1	55.5 69.4	5 3
Brindley (23)	1937	76	52.4	3 9	63	5 or more
Gabriel (41)	1937	100		22.0	52	5
Miles (76)	1939		65	17.0	73	5
Scarborough (93)	1939	66	95.6	9.09	62	3 or more
Hayden (51)	1939	82	76.6	13.4	20	3 or more
Pfeiffer (85)	1941	82	59	12.8	45	5 or more
Cattell (24)	1943	162 (1932 to 1936)			53.6	5 to 10

served." In my own series of 208 radical resections, the sphincters were preserved or continuity immediately established in 167 cases, or 80.3 per cent.

Does preservation of the sphincter musculature augment the operative mortality? Mandl (72) is quite definite that it does not. In a combined series of 414 radical resections for cancer, Babcock (10) and the writer reported a mortality rate of 6.6 per cent for 212 cases of abdominoperinal proctosigmoidectomy without colostomy, and 4 per cent for perineal proctectomy without colostomy. Immediate establishment of intestinal continuity for upper rectal, rectosigmoidal, and low sigmoidal growths has but recently become popular, and, while the mortality rate is slightly higher, it may be assumed that, with added experience, the rate will be decreased. It will be noted that, except for the group reported by Dixon, namely 206 cases, the series are not large. Zinninger and Hoxworth, who prefer this method, cite 18 sigmoidal resections with 2 deaths—an operative mortality of 11.1 per cent. Babcock performed 76 single clamp aseptic one stage resections with 7 deaths, or 9.2 per cent. Excluding those in which operation was done as a palliative procedure, the mortality is 4.3 per cent. Wangensteen (98) reports 28 cases and Horsley 3 cases without a death. Over a 12 year period, Dixon reports a mortality rate of 12.1 per cent and 32 per cent, respectively, for those with a view of cure and those as a palliative procedure. Of 41 cases recently performed, his mortality rate was 2.4 per cent. Fallis published a series of 31 cases with a mortality rate of 6.5 per cent. During the past year, we have employed immediate end-to-end anastomosis in 16 instances, 12 with a view of cure and 4 as a palliative procedure. My first 2 patients died, due, I feel, to too much reliance upon indwelling duodenal siphonage. Since that time, complemental decompression—usually appendicostomy—has been employed without death. The mortality rate for the 16 cases, however, is 12.5 per cent. A distinct advantage of re-establishment of bowel continuity in the pelvis is the avoidance of impotence, so common in abdominoperinal extirpations. Jones (58) found the incidence to be 95 per cent.

It is difficult to compare the survival rate of an operative technique in which the sphincters are preserved with those in which the muscles are sacrificed, because of the relative infrequency of performance and sparsity of reports of the former. In citing the experience of various surgeons as to cure, the percentage of operability (resectability) should be considered, as well as the mortality. Attention is called to the fact that for the most part the following reports were published a few years ago. It is only fair to assume that, if more recent data were available, the resectability and survival rates would be increased and the mortality decreased.

Passler surveyed the results achieved by several European surgeons, including Eiselsberg, of Vienna, Payr, of Leipzig, Sauerbrook, of Munich, Gulede, of Jena, and Kirschner, of Tuebingen, the average 3 and 5 year cures of which were 29 per cent and 23 per cent, respectively.

In contrast are a few reports where the sphincter muscle was not sacrificed. For example, Mandl (71, 72) states that "preser-

vation of the sphincters does not influence the lasting results adversely." Based on a series of over 1,000 operations, the percentage of 3 year cures was higher in cases in which the sphincter apparatus was preserved (33 to 37%) than when sacrificed (25 to 31%). He maintains that similar results were obtained by Eichhoff (Kuettner clinic) and Pribram (Payr clinic). Our combined group of cases is shown in Tables I and II.

What degree of continence has been experienced following various procedures to preserve the sphincter muscle? Mandl (71), an ardent advocate of the Hochenegg method, reported that of the cases in which circular suture was performed, 19.3 per cent of the patients were discharged as continent; complete control was effected after a period of time in 49.4 per cent. Following the "pull-through" method, the number of continent patients increased from 58.3 per cent to 64.5 per cent. In contrast, however, is the publication by Koerbl of the Eiselsberg Clinic who observed complete continence in 36 per cent employing Hochenegg technique and 66 per cent with the Kraske method. Gersuny recorded satisfactory continence in 75 per cent of his cases. Du Pan, a pupil of Kocher, reported that 8 patients had complete and 32 partial control; 11 were completely incontinent. In a discussion of continence, one should be mindful that preservation of the sphincter musculature is not necessarily synonymous with preservation of the sphincter function. During the perineal portion of the operation "proctosigmoidectomy," even though the external sphincter is preserved, its innervation, namely, the inferior hemorrhoidal and perineal nerves, derived from the second, third, and fourth sacral plexuses are surgically intercepted; also, the small filament from the fifth sacral and coccygeal plexus—the lesser sphincterian nerve of Morestin; yet, following operation, and in many cases within a few days, voluntary contraction can be observed subjectively and objectively. One recalls the experiments of Elliott who found that the external sphincter, even when separated from its nerve supply, was not prone to degenerate as is characteristic of other voluntary muscles. That it retains the responsiveness to the faradic

TABLE II.—RESECTED—NOT COLOSTOMIZED

Name	Year reported	No. cases	Resectability cure or relief %	Mortality rate %	Survival no. cases to 144 traced	
					%	Years
Babcock and Bacon (10)	1943	414	93	6.6	81 38	1 to 3 5 to 10

Abdominoperineal proctosigmoidectomy	6.6
Perineal proctosigmoidectomy	4.0

current is shown at the time of sphincteroplasty, usually 10 days after proctosigmoidectomy. In some 160 cases, sphincteroplasty has been performed by means of a faradic stimulator especially designed by George C. Henny, M.D., director of Research Physics at the Temple University Medical School. As will be described under technique, the sphincter musculature is divided posteriorly; it is dissected free and retracted anteriorly and laterally. Preservation of the three strata of muscle bundles composing the external sphincter offers little difficulty except that it is a trifle tedious. Approximation of all divided musculature is effected at the time of operation except the posterior quadrant of muscle, because of the necessity of presacral drainage. Our great problem lies with the internal sphincter which, in itself, is a most important structure. Designed to aid in the expulsion of feces, it also assists to occlude the anal aperture by tonic contraction. This muscle, representing an aggregate of inner circular muscle fibers of the rectum into a single component, measuring 2 to 5 millimeters in thickness and 1 to 3 centimeters in width (49), and innervated primarily by the sympathetic and parasympathetic nerves, maintains perfection in control, especially of flatus and liquid feces. With this operation, efforts to preserve this involuntary muscle have not been too pleasing. By the same token, while we feel that the somatic or cerebrospinal innervation to the external sphincter is but minimally impaired, the visceral innervation to the internal sphincter is definitely interrupted. The investigations of Goltz and Ewald on dogs are very interesting and bear some influence on our problem. These workers, who were able to keep their animals alive for years after transection or destruction of the spinal cord below the seventh cervical segment, observed that

while diarrhea was interposed, defecation gradually became normal: one or two evacuations were noted daily, and on each occasion the rectum was well emptied. Patients following proctosigmoidectomy are capable of voluntary muscular contraction of varying degree, noted subjectively and objectively. Approximately 80 per cent of our patients may be classified as continent, yet perhaps 40 per cent wear a protective pad or strip of gauze, not of necessity but often because a sense of security from soiling is afforded. Truly, our most difficult task is with constipated individuals who for a period of years have become accustomed to the habitual use of cathartics.

TECHNICAL FACTORS

Thus far, our purpose has been to consider the development of surgery of the lower intestine and colostomy elimination, to answer inquiries and compare various procedures in which the sphincters are preserved, including "proctosigmoidectomy" with colostomized extirpations. A substantial series of cases, namely, 732 resections of the colon and rectum performed without colostomy by Babcock and the writer and recently reported (11, 17) from their respective services, the department of surgery and the department of proctology, has served to support previous discussion. We shall now consider our experiences and the technical factors of this operation for which reason my own series of 256 cases of cancer of the anus, rectum, and sigmoid colon from the department of proctology for the 3 year 7 month period ending April, 1944, has been reviewed. In this group there were 143 males and 113 females; 236 were white and 20 or 8 per cent were colored; the average age was 53.2 years, the extremes 17 and 85. The distribution was as follows: sigmoid 27, or 10.54 per cent; rectosigmoid, 87, or 33.9 per cent; rectum, 132 or 51.17 per cent; and anus, 10 or 3.9 per cent. The histologic type in 236 of the 256 cases was reported: adenocarcinoma, 223 or 94.4 per cent; epithelioma—squamous cell, 6, basal cell 1; malignant melanoma 2, fibrosarcoma 2, and leiomyosarcoma 2. Tumors were graded according to Broder's classification in 219 instances: grade I, 17 cases, grade II, 127 or 57.9 per cent, grade III, 67, and grade IV, 8.

Of 256 patients, I personally resected 208, an operability or resectability rate of 81.2 per cent. The remaining 48 patients were treated by palliative colostomy, exploration and closure, local excision or fulguration; others refused operation or sought counsel elsewhere. The operative mortality of the 208 cases (16 deaths) was 7.6 per cent. This group included such procedures as the Mikulicz and Rankin modification, Babcock's single clamp method of sigmoidectomy, and those designed by Cuneo, Miles, Lahey, Turner, Hartmann, and Lockhart-Mummery; 145 were performed by the Babcock technique of abdominoperineal or perineal proctosigmoidectomy without colostomy and with an anal sigmoidostomy.

As is our custom, all patients are admitted to the hospital 5 to 7 days prior to operation. A complete examination, including cystometric studies, is made and the patient is placed in fluid, caloric, nitrogen, and electrolyte balance. Fluids freely by mouth are encouraged—a minimum of 2500 to 3500 cubic centimeters daily, unless contraindicated. Since 29.7 per cent of our patients with rectal and sigmoidal cancer showed hypoproteinemia during the preoperative period, the nitrogen equilibrium is established and maintained by a low residue diet in four feedings: carbohydrate, 400 grams; protein, 120 grams; fat, 50 grams; and amino acids (casein hydrolysate reinforced with tryptophan) 300 to 400 cubic centimeters (15% solution) orally each day. One or more blood transfusions are administered in quantities sufficient to raise the erythrocyte count to four and one-half million. To assist in avoiding hemolytic transfusion reactions and their sequelae, sodium bicarbonate sufficient to maintain a urinary *p*H above 7.0 is given. We have come to realize that there is a high incidence of subclinical avitaminosis previously unsuspected, but a potentially dangerous stage, which may occur as the result of diet, inability to utilize vitamins, failure of absorption of fat-soluble vitamins in the absence of bile, or depletion of vitamin reserve by excessive demands in malignancy. Routinely, by mouth, thiamin chloride, 50 milligrams; nicotinamide, 100

Fig. 5. Mobilization of the bowel posteriorly is accomplished by gentle but firm introduction of the hand into the presacral space as far as the sacrococcygeal articulation. Anteriorly the rectosigmoid is bluntly dissected from the upper portion of the vagina, or from the prostate and seminal vesicles.

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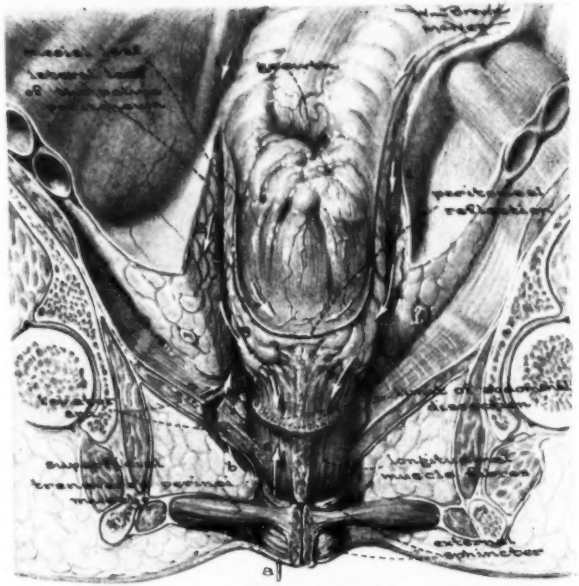

Fig. 6. Schematic drawing showing incision of both peritoneal leaves, *1* and *2*. From the abdominal phase the rectum is shown mobilized anteriorly as far as the prostate and seminal vesicles, *3*, or vagina and laterally to the levators, *b*. From the perineal phase of the sigmoid, the sphincter and transverse perineal muscles are divided anteriorly and preserved. The dissection is continued from *a* to a^1 to and through *b*.

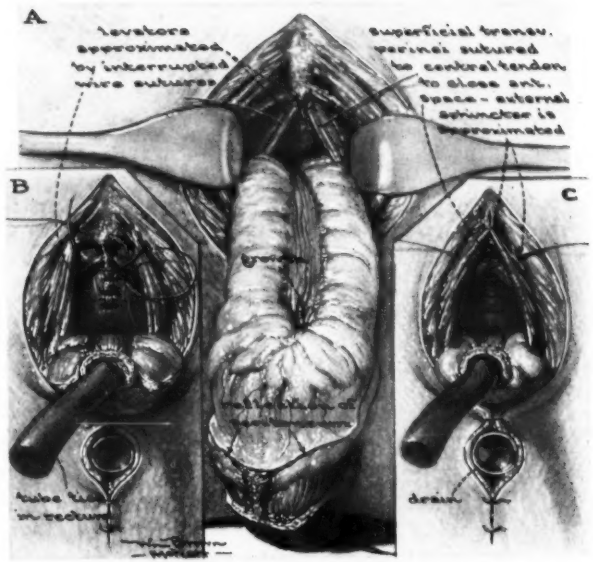
A
levatores approximated by interrupted wire sutures
superficial transv. perinei sutured to central tendon to close ant. space - external sphincter is approximated
B
C
drain

Fig. 12. A, Cancerous bowel drawn through the wound; anterolateral floor has been established from the peritoneal reflection. Approximation of anterior levator fibers is shown. B, Bowel has been cut away and rubber tube tied in sigmoid. Transverse perinei are sutured. C, Sphincter muscles sutured to original status.

milligrams; ascorbic acid, 100 milligrams; and pyridoxine, 5 milligrams are prescribed daily. On the fifth preoperative day, a nonabsorbable sulfonamide is begun by mouth and continued to the morning of operation. Sulfasuxidine, succinylsulfathiazole, which we have employed in 131 cases (102 proctosigmoidectomies) of our total series is given in an initial dose of 0.5 gram per body kilogram weight, followed by a dosage of 0.25 gram per kilogram every 4 hours. More recently sulfathalidine, phthalylsulfathiazole, a sulfonamide having a similar mode of action, has been used in 54 cases, including 19 proctosigmoidectomies. The initial dose is calculated on the basis of 0.1 gram per kilogram weight; the maintenance dose is estimated upon the same basis.

All patients in this series, with the exception of 2 with acute intestinal obstruction, irrespective of age or general condition, were operated upon under spinal anesthesia. During the past 18 months, fractional or continuous spinal anesthesia has been employed, the Woodbridge formula of 0.3 per cent pontocaine in 7 per cent dextrose solution being used.

OPERATION

Abdominal phase. The abdomen is opened through a left oblique incision 3 centimeters above the inguinal ligament, beginning at a point medial to the anterior iliac spine and ending to the right of the midline above the pubic spine. Ordinarily, the left anterior rectus sheath is divided and, in a few instances, we have detached both the rectus and pyramidalis muscles from the pubic spine as suggested by Cherney. The liver is examined for metastasis; the median lumbar, upper and lower mesocolic areas palpated for nodules, and the extent of the growth determined. The patient is placed in the Trendelenburg position and the pelvic cavity is cleared of small intestine by hot packs. The left lateral leaf of the mesosigmoid is freely divided wide of any malignant infiltration, the incision being carried downward to the rectovesical or rectouterine sulcus. In the course of the dissection, the left ureter, iliac, and the spermatic or ovarian vessels are exposed. The spermatic or ovarian vessels may be divided and ligated. The sigmoid with attached fat and mesosigmoid is mobilized toward the midline. The peritoneum on the mesial side of the sigmoid is incised downward, continued around the right pelvic brim, and across the sulcus between the rectum and bladder or uterus to meet its fellow of the opposite side.

Ordinarily, transillumination is employed to visualize the inferior mesenteric, superior hemorrhoidal, and sigmoidal vessels, and their communicating arcades. By such, greater precision can be exercised of those to be preserved, which is essential for that portion of the sigmoid to reach through the perineum. The necessary vessels are clamped, divided, and doubly ligated. If desired, the lateral peritoneal leaflet of the descending colon may be divided in order to slide the bowel to a lower position. Having determined the point of viability by observing pulsating arteries or by the character of the bleeding when the small vessels on the surface of the bowel at the level of resection are incised, it is identified with black silk. By gently inserting the hand into the postrectal cellular space in the pelvis, the lower pelvic sigmoid and rectum can be stripped from the anterior surface of the sacrum as far as the sacrococcygeal articulation. The lateral ligaments are rendered prominent and divided as far as the upper surface of the levator ani. They may or may not require ligation. Anteriorly, the rectum is separated in the female from the upper portion of the vagina, and in the male from the base of the bladder as far as the prostate. Care should be exercised to avoid injury to the seminal vesicles and vas deferens. Five grams of sulfathiazole powder are dusted over the viscera which is covered by the great omentum, and the peritoneum is closed. Interrupted sutures of No. 32 gauge alloy steel wire are introduced for fascia, and No. 35 for skin.

Perineal phase. The patient is changed to the lithotomy position on the specially designed spinal mattress, and the rectum is packed loosely with antisepticized gauze. The anal canal is closed at the pectinate or anorectal line by a strong pursestring suture. A posterior incision is made behind the closed anus and carried around and immediately below the closed anorectal line. The sphincter

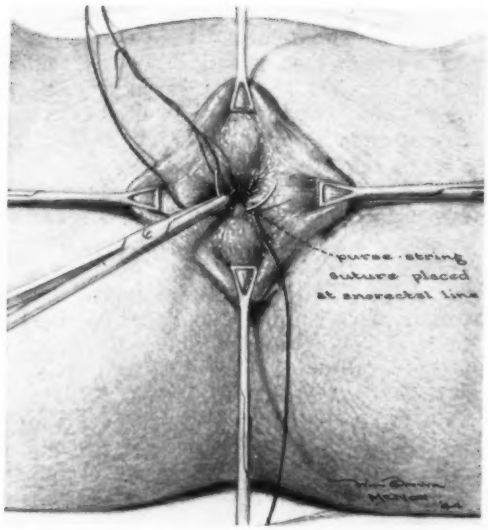

Fig. 7. Perineal phase. Anal canal is closed by purse-string suture which is placed exactly at the anorectal (pectinate) line.

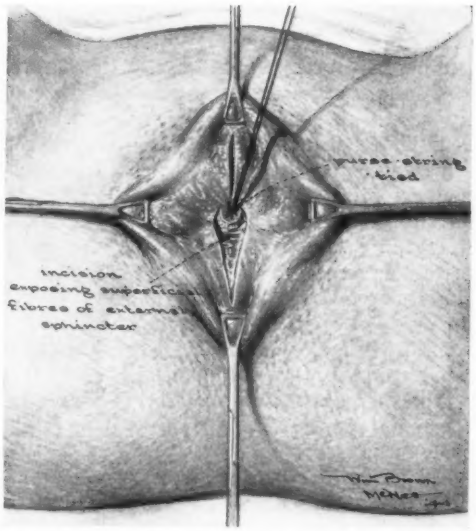

Fig. 8. Incision is made in front of and behind the closed anus, and is joined by a circular incision close to the purse-string suture.

muscle is identified, separated, and retracted as is done in our operation for hemorrhoids(14). The sphincter muscle is divided posteriorly. Usually, a single transverse incision through the fascia propria, which is closely adherent to the periosteum of the lower border of the sacrum, is all that is needed to mobilize the rectum posteriorly. By making traction on the bowel, the levator ani muscles are placed on the stretch, provided the lateral ligaments have been divided during the abdominal phase. The levators are clamped, severed, and ligated. Anteriorly, the superficial and deep transverse perineal muscles are retracted. Cautiously the line of cleavage between the rectum and prostate is followed until the base of the bladder and the seminal vesicles, with the vas deferens, come into view. In the female, the rectovaginal septum is separated by blunt and gauze dissection until the upper portion of the posterior wall and uterus are exposed. Mobilization being complete, the rectum and lower sigmoid are drawn through the wound and enclosed in a towel. The segment of bowel identified with black silk noting viability should protrude well beyond the skin margin. An anterior pelvic floor is established and the perineal and anterior sphincter muscles are permitted to assume their normal position. A curved, perforated, metal drain is inserted posteriorly along the sacrum to evacuate blood and serum during the first 48 hours. Dressings are applied; the extruding bowel is slit at point of, or above, viability (5 to 7 centimeters) to allow for retraction, and a 28 gauge rubber tube is placed and tied in the bowel. This rubber tube is removed after the first bowel movement—usually the 3d or 4th postoperative day.

In this group, namely 145 cases, invasion of other organs at the time of operation was encountered in 26 instances, or 17.9 per cent. Distribution and surgical disposition was as follows: Small intestine was involved in 5 instances, resection in all (1 death); bladder in 5, with partial resection in 4; uterus in 2, hysterectomy in both; vagina in 6, posterior wall resected in all; prostate in 6, partial or complete in all; ureter in 1, resected; abdominal parietes 1, wide excision. Liver metastasis was found in 17, or 11.7 per cent. Invasion of regional lymph nodes determined by microscopy was observed in 54, or 37.2 per cent.

Of the 145 patients 137 survived the operation, a mortality of 5.5 per cent. The 8 deaths were as follows: peritonitis in 4, pulmonary embolism, 2; pneumonia, 1; and myocardial failure, 1. This was an unselected group, excluding growths within 3 centimeters of the sphincter musculature (6 cm. of anal margin). In this series, there were 49 consecutive resections with 1 death, an operative mortality of 2.04 per cent.

Postoperative treatment. The transfusion of whole blood given during the operation is followed by 5 per cent glucose in isotonic saline solution; additional blood and plasma are ordered if there is any doubt as to their need. Inhalation of high concentration of oxygen is given for a minimum of 24 hours, for the purpose of effecting a reduction in the amount of nitrogen, thereby diminishing intestinal distention (40). Wangensteen suction is in force during the operation to avoid vomiting and regurgitation of vomitus into the lungs, which according to Wangensteen (99) is the most frequent cause of postoperative pneumonia, and is continued for 48 hours or more.

The patient's status as to hydration and acid-base balance, which cannot be divorced from each other, is of utmost importance. Dryness of the skin, thirst, and capillary turgor, but especially the urinary output per 24 hours, vaporization from skin and lungs, comparison with preoperative fluid balance and blood studies; the plasma protein, specific gravity of blood plasma and whole blood, cell volume of venous blood by means of the hematocrit and McClure-Ulrich test for tissue avidity are helpful indices, while total serum carbon dioxide content and serum chloride, daily urinary chloride concentration, loss by perspiration, by duodenal suction and by the Babcock intra-abdominal sump drain, will help to ascertain electrolyte status.

Nitrogen balance and the level of the blood protein have but recently been recognized as important parts of the preoperative and postoperative care of the cancer patient. It must be realized that there is a period of approximately 72 hours following proctosigmoidectomy when parenteral administration must of necessity be employed if nitrogen equilibrium is to be maintained. As previously reported

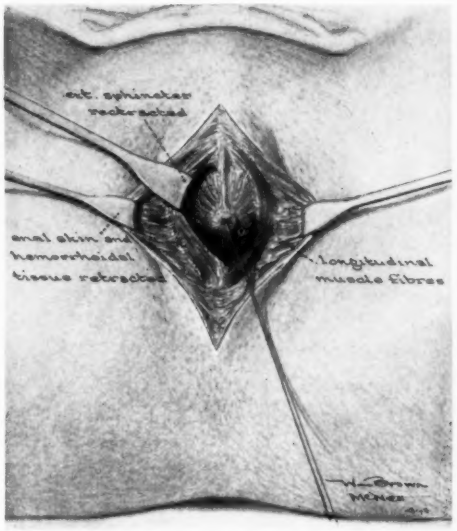

Fig. 9. By gentle traction, the sphincter muscles are teased from the rectal wall and retracted laterally.

(16) in a series of 57 patients, 42 or 73 per cent were held in positive nitrogen balance after operation by the administration of whole blood, blood plasma, and amino acids in liberal quantities. In other words, 15 or 27 per cent showed serum protein levels below 6.5 grams per 100 cubic centimeters. In contrast, however, were 17 patients, in whom no treatment was given, of which number 15, or 88 per cent, became hypoproteinemic.

It is our practice following resection to give 2,500 to 4,000 cubic centimeters of fluid each day during the immediate postoperative period or until the patient can tolerate sufficient quantities by mouth. The amounts and values usually required to maintain fluid, caloric, nitrogen and acid-base balance, approximate the following: 1,000 cubic centimeters 10 per cent glucose in sterile distilled water; 1,000 cubic centimeters 10 per cent glucose in physiologic saline solution with 300 cubic centimeters amino acids (15 per cent sol.); sodium lactate[1] (1–100 cubic centimeters ampul of M/6 sodium lactate dis-

[1]The amount of one-sixth molar solution sodium lactate needed is computed by daily estimation of the carbon dioxide content; e.g., kilogram weight of patient times carbon dioxide deficit (65 vol. % accepted as normal) times 0.026=amount of $NaHCO_3$ in grams.

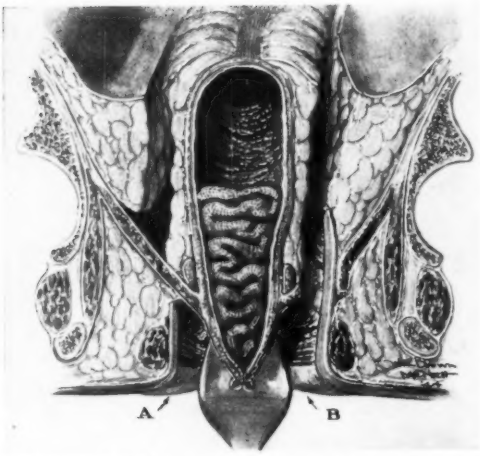

Fig. 10. *A*, Sphincter muscles are retracted laterally exposing the levator ani. *B*, Levator muscles have been clamped, divided and ligated. Gauze saturated in an antiseptic solution is shown in the closed rectum.

solved in 500 cubic centimeters 10 per cent glucose in sterile distilled water represents a one-sixth molar solution and is equivalent to 8.4 grams sodium bicarbonate); sodium sulfathiazole, 2½ grams twice daily dissolved in 40 cubic centimeters of sterile distilled water; blood plasma or lyovac, 250 cubic centimeters daily, and whole blood 500 cubic centimeters on 1st and 3d postoperative day. Such represents a fluid intake of 3,480 cubic centimeters; a caloric value of 1269.5; nitrogen 16.5 grams; sodium chloride 11.6 grams, and sodium bicarbonate 16.8 grams.

Ordinarily the intravenous route of administration is employed, but when access to veins is difficult, we do not hesitate to utilize the subcutaneous and intrasternal means of injection. In no instance have we encountered any untoward reaction with blood, blood plasma, glucose, and saline or amino acids (5 per cent solution) when the intrasternal route has been used.

The resources offered by modern chemotherapeusis are of paramount value in preventing and combatting infection, especially peritonitis. Patients are given sodium sulfathiazole 2½ grams twice daily beginning the morning following operation. Guides are the urinary output, the blood sulfathiazole level, and the number of erythrocytes in the urine. Sodium bicarbonate is used routinely. If the intravenous and oral routes are not feasible, 0.8 per cent sulfanilamide in one-sixth molar solution sodium racemic lactate is injected subcutaneously.

Sulfasuxidine, succinylsulfathiazole, is given in suspension in the same dosage as before operation, namely 0.25 gram per kilogram body weight every 4 hours as soon as the patient is able to tolerate liquids by mouth, usually on the 3d or 4th postoperative day. As previously reported (17), in our series of 145 cases in which an abdominoperineal proctosigmoidectomy was performed, there were 8 deaths, 4 of which were due to peritonitis. Of these, namely 4, only 1 had been given sulfasuxidine preoperatively but not postoperatively. Sulfathalidine, phthalylsulfathiazole, has been employed more recently in 54 resections (19 proctosigmoidectomies). The drug is given postoperatively in amounts equal to the preoperative dose, namely 0.1 gram per kilogram body weight every 4 hours in suspension as soon as liquids are tolerated by mouth. A definite decrease quantitatively of the coliform organism has been noted by stool culture. In no instance have we encountered any untoward reaction. It may be mentioned that of our total series of 208 resections to April, 1944, including those to September, 1944, intra-abdominal soiling occurred in 11 instances as the result of perforation at the time of resection, contamination in open anastomosis, or slipping of the clamp in closed anastomosis, yet there has been no fatality.

Abdominal wound infection and dehiscence have been infrequent complications, and, to a great measure, we believe that it has been due to the maintenance of adequate protein and vitamin C levels and to the use of oblique muscle splitting incision and Babcock's alloy steel wire. In our series there were 2 instances of abdominal wound infection in 145 cases, or 1.3 per cent.

Following proctosigmoidectomy patients are permitted out of bed usually on the 6th to 9th day, and recently the majority have been discharged from the hospital on the 12th postoperative day. Approximation of the posterior sphincter musculature is made be-

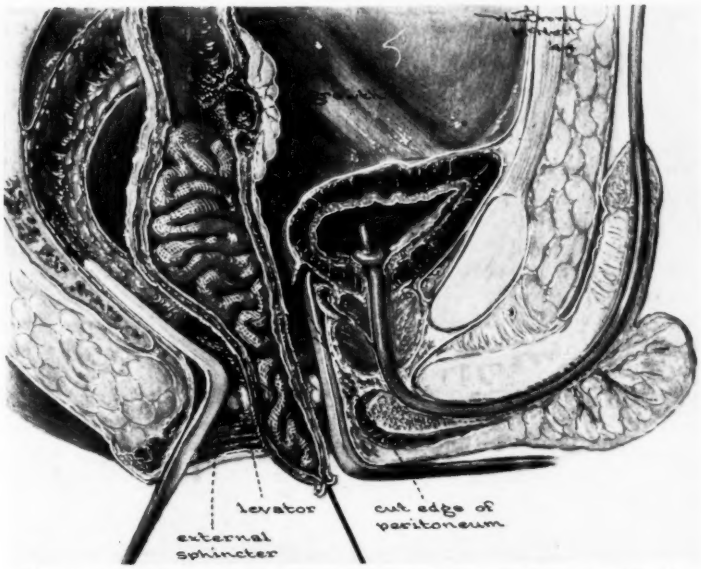

Fig. 11. Sagittal section showing tension on closed rectum. Lateral mobilization having been completed, the bowel is freed posteriorly by a single transverse slit. Anteriorly the dissection is continued to the summit of the prostate or upper vaginal wall. A Foley catheter is shown in the bladder.

fore the patient leaves the hospital, but, if there is purulent drainage from the presacral area, the sphincteroplasty is postponed for a month. This operation requires not more than 3 days' hospitalization.

It is worthy of mention that the presacral wound consumes about 3 weeks for complete healing and closure—approximately that of an ordinary anorectal fistula. Thus, in the majority of our recent cases patients have been able to return to their former or perhaps lighter occupations in an average of 6 to 10 weeks following operation. In our other types of abdominoperineal extirpations, in which a large perineal wound is made, at least 3 months was the average period required for healing (15).

SUMMARY AND CONCLUSIONS

The evolution of surgical extirpation for rectal and low sigmoidal cancer designed to eliminate the establishment of an abdominal colostomy has been discussed. A serious effort is being made in this respect. It has been shown that preservation of the sphincter muscles does not augment the operative mortality. In more than 80 per cent of the cases, the sphincter musculature may be preserved, and, so far as one can judge, it does not affect the rate of survival.

From a gross series of 712 cases in which radical resection was performed without colostomy, a group of 208 personal extirpations of the rectum and sigmoid for carcinoma has been selected as the basis for this discussion, and, therefore, an attempt has been made to evaluate and compare impartially this series with other present day procedures.

It is our opinion that the Babcock abdominoperineal technique of proctosigmoidectomy without colostomy and with preservation of the sphincter muscle possesses merit. It permits radical removal of the malignant bowel and gland-bearing areas, and, in spite of a high rate of resectability (81.2%), enjoys a low operative mortality, 5.5 per cent in 145 resections; 2.04 per cent in 49 consecutive resections: it allows early discharge of the patient from the hospital, reduces the period of wound healing, and affords early return to work.

Improvements and refinements in technique, such as the establishment of an anterolateral pelvic diaphragm, have prevented descent of small bowel into the perineal wound; precise maintenance of essential blood supply, has avoided retraction and necrosis, and preservation of the sphincter musculature has offered varying degrees of continence. It must be realized, and we are frank to admit, that the sphincter function following proctosigmoidectomy is not perfect nor that for which we strive, yet in approximately 80 per cent of our cases, continence is cited and between 90 to 95 per cent of patients are able to carry out their daily occupations without inconvenience. If one may judge from the 51 patients in whom the abdominal colostomy was transplanted to the perineum, then a perineal anus or anal sigmoidostomy is a distinct improvement over even a well constructed stoma in the abdomen.

Finally, the physiologic derangement of patients with rectal cancer, in whom extirpation is contemplated, is deserving of careful consideration, and, therefore, special attention should be directed toward the maintenance of the fluid, caloric, nitrogen, and acid-base balance.

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EXPERIENCES WITH ANEURYSMS IN AN OVERSEAS GENERAL HOSPITAL

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THIS report is limited to arterial injuries which have not necessitated ligation at the time of the original débridement. In a general hospital in a theater of operations the majority of such cases consist of aneurysms, either false or arteriovenous in type. The term "pulsating hematoma" is used interchangeably with false aneurysm to designate any arterial leak which results in a blood or clot filled sac into which the artery is continually pouring some blood, so that a palpable thrill, or an audible bruit, or a steadily enlarging mass are characteristic findings. The enclosing sac may be little more than partially organized clot bounded by muscle, fascial or skin surfaces; or it may be a fibrous, firm, reasonably stable envelope, depending upon the site or duration of the lesion. In loose areolar tissue, such as the retroperitoneal space, a leaking artery gives rise to a progressively enlarging hematoma. Although pulsation and bruit may not be detectable, the process has the characteristics of a false aneurysm, i.e. it has the opening in the artery, the same progressive enlargement and possibility of hemorrhage. Arteriovenous aneurysms, although of considerable interest, do not constitute as much of a problem in this theater as do the false aneurysms. For this reason emphasis is laid upon the latter.

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Fig. 1, a and b.

(*Legend on opposite page*)

The lesions which we are discussing represent arterial injuries that are not usually apparent at the time of the initial débridement. They are caused by a variety of missiles. The series includes gunshot wounds (rifle, machine gun, revolver) and all sizes of shell fragments. In the formation of an aneurysm there must be one constant condition, however: the injury to the vessel must be partial and therefore a small fragment is the usual cause. Should complete severance of a vessel occur, retraction and clotting will take place, or the vessel will have to be clamped and tied, and no aneurysm will be formed. These are the problems of the forward hospitals. In only 1 of our cases was this condition not apparent (see Case 9).

We have observed 30 cases of aneurysm in the past 20 months of overseas operation. Of these, 20 have been false and 10 arteriovenous in type. Figure 1 reveals several significant facts. Nineteen of the 20 patients with false aneurysm were operated upon. Serious hemorrhage, either externally or internally into the tissues, was the indication for emergency surgery in 12 of these. The duration of the lesions varied from 4 days to 3 months. In the arteriovenous group of 10 cases, all of them involving major vessels, no patient was operated upon for hemorrhage. If the decompression effect of the attached vein is considered this result is to be expected. Further, the series shows that gangrene should rarely

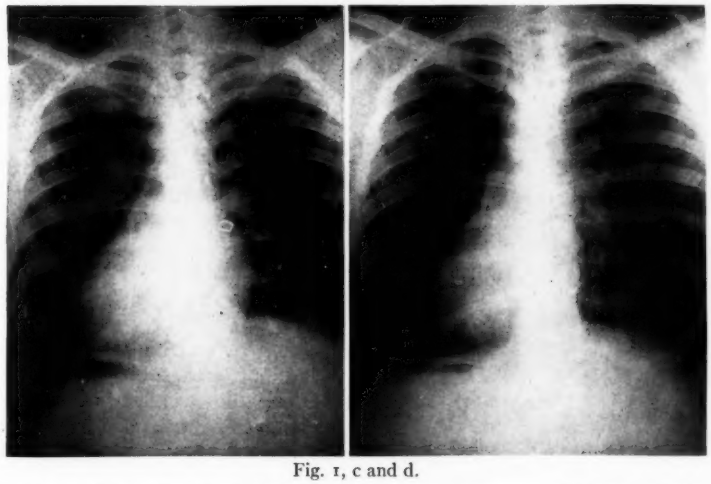

Fig. 1, c and d.

Fig. 1. X-ray films from Case 16. Arteriovenous aneurysm of femoral vessels. a, Diodrast study before release of the compressed artery, showing the fistula, dilated veins, beginning filling of the sac. b, Diodrast study immediately after release of the compressed artery, showing complete filling of the false sac. c, Six foot chest film showing preoperative cardiac enlargement. d, Six foot chest film showing return of heart to normal, 2 weeks after operation.

follow ligation of major vessels if there has been an adequate time interval for the development of collateral channels, and time for the restoration of blood, which may have been lost in large quantity after the patient was wounded.

Often the presence of the lesion is not discovered for some days or weeks. Perhaps many small leaks seal off and never break down. In some the vessel wall may have only been contused, with later rupture through the weakened wall. In 1 case, not reported here, a false aneurysm of the brachial artery made its appearance 3 months after injury. In the arteriovenous type there is almost always a period of a few days before a diagnosis is made; often it is weeks or months. In this connection it might be well to predict that many of these lesions will be discovered in the zone of the interior, since small fistulas may cause no symptoms.

Diagnosis is very simple in almost all cases in which a mass or audible bruit is discovered. There may be associated pain. The murmur heard over the false type has been systolic in time in all our cases. Often the actual vessel involved may be difficult to determine, but it is always assumed to be the major vessel until proved otherwise. In all of the arteriovenous aneurysms the murmur has been continuous, with a systolic accentuation. In this type the slowing of the heart rate upon obliteration of the fistula is pathognomonic (Branham's sign); the reflex blood pressure changes have not been constant in the early cases. In certain vessels this test cannot be applied, e.g. the subclavian. Venous pressure measurements may help.

Differentiation between the two types of aneurysm is essential because of the difference in treatment. Not only are the arteriovenous cases safe for transport but they seem to require a longer period for the establishment of adequate collateral circulation. Hence these patients usually are evacuated to the zone of the interior unless intervention is indicated because of increasing nerve symptoms, the association of a large unstable false sac, or because it is necessary to improve the distal circulation which has already been shown to be inadequate.

Changes in cardiac physiology of a serious nature are not anticipated for 3 months at least. In Case 16, almost 4 months after

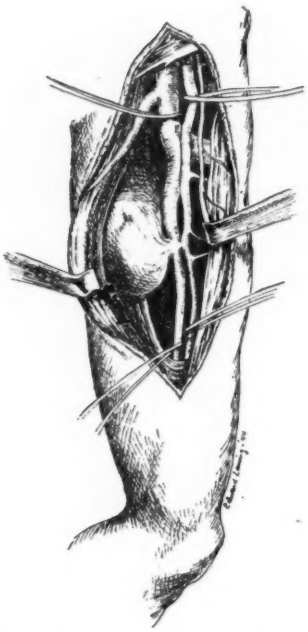

Fig. 2. Drawing at operation in Case 16.

wounding, there was demonstrable cardiac enlargement; but the return to normal was rapid following operation. Tachycardia may be noted early, especially in fistulas near the heart; but since the Army patient remains in a hospital throughout the course of his illness, observation will preclude any deleterious effects. Embolism arising from either type of aneurysm has not been noted in this series.

There is one pitfall in the diagnosis. A firm, hard mass over which the skin is reddened is not necessarily an abscess. In Cases 2 and 12 a preoperative diagnosis of abscess was made. In Case 12 considerable nimbleness was required to prevent fatal hemorrhage. In another "abscess" beneath the angle of the jaw incision resulted in a sizeable stream of blood from the internal maxillary artery which, although easily controlled, was quite unexpected. Aspiration of any suspicious mass should always be done first. When clot or blood is found, attention is directed immediately to the proximal and distal control points.

At the base hospital, under careful observation, it is justifiable and desirable to postpone intervention as long as possible. Risk of hemorrhage or critical diminution of circulation is lessened by means of pressure dressings, immobilization, and perhaps sympathectomy. Every effort is directed toward carrying a limb long enough to survive on its collaterals when complete obliteration of the channel becomes necessary. The majority of the limbs distal to the false aneurysms present a palpable pulsation even when the leak is a large one, showing that some blood is reaching the limb through the main vessel. Thus a slowly enlarging aneurysm or a hematoma may be looked upon as a desirable safety valve in any case in which early ligation otherwise will result in gangrene.

Collateral circulation, anatomically, consists of a reasonably constant set of vessels which may take over the blood supply to a part in the event of interruption of the main artery at any given point. Physiologically there is little that is constant about it. Swelling, spasm, and infection play important rôles. The evaluation of the adequacy of collateral circulation may be very difficult. If the vessel proximal to the site of injury is available for selective compression, Matas' test is easily applied. In many of the cases this procedure has not been possible, and, since the majority of the operations have been on an emergency basis, the prognostic value of such procedures is slight in false aneurysms. However, in the evaluation of the case, there are certain guides to the safety of future operation. A diminished or absent arterial pulse in a warm or pink distal extremity obviously is a good omen, for one is certain that pressure is being put upon the collateral channels which are already functioning. A normal pulsation prompts one to prolong the observation period as long as possible.

When the circulation is critical, certain observations are made to determine whether or not it is safe to observe longer. The presence or absence of a distal arterial pulse is determined manually or by means of the sphygmomanometer. The temperature is noted with the part exposed to room temperature and the

blanching reaction noted by elevation of the limb to 30 or 40 degrees. The color is quite important, but may be a poor sign in dark-skinned individuals. Pinkness is always a good sign, but cyanosis may be misleading in that fairly good circulation may exist in its presence. Whiteness is, of course, significant. Nail bed reactions to pressure have been found very valuable. More elaborate tests, even when possible in this theater, have not been found to be necessary. Decisions which are based upon the data mentioned have proved sufficient.

In critical cases the value of interruption of sympathetic impulses is very great. In the emergency cases such treatment can be carried out immediately prior to the attack on the vessel. In elective cases it is usually done a week before. The danger of initiating spasm during operative manipulation is reduced. Five cases have been sympathectomized—3 femoral lesions and 2 popliteal. In all it was felt that the procedure was of definite value. Novocain block of the sympathetic chain, single or repeated, was done in 3 cases—1 femoral and 2 popliteal aneurysms. The blocks seemed helpful in all cases, but whether essential or not could not be said. No help was needed in any of the upper extremity cases and no blocks were done. If uncertainty as to the adequacy of circulation following proposed obliteration of a large vessel exists, especially in emergency procedures, it would seem unjustifiable not to employ sympathectomy if the patient can tolerate additional surgery. In the lower extremity the procedure may be necessary for the later rehabilitation of the limb anyway. Novocain block as a test of the efficacy of proposed sympathectomy has not been satisfactory. Usually the need is urgent and permanency is desired. Lumbar sympathectomy is performed through a muscle-splitting flank incision with resection of the 2nd, 3rd, and 4th ganglia.

In the series of false aneurysms there were 6 cases with associated nerve injury. If the minor vessel and retroperitoneal cases be omitted, this incidence becomes 60 per cent. The high rate is to be expected because of the proximity of the nerves to the great vessels.

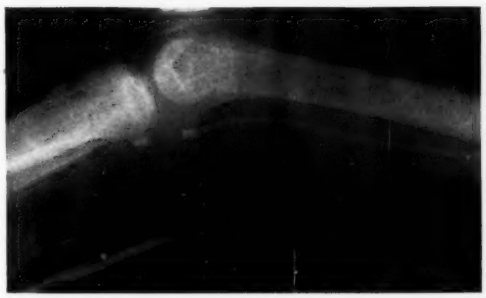

Fig. 3. Diodrast study of the anastomotic connection in Case 9, 11 days after operation. The channel is not patent in this film. See text.

Although, of course, primary consideration must be given to the vascular lesion, increasing nerve symptoms may hasten the elective operation. At times ischemic paralysis must be distinguished. The increasing toughness of the fibrous tissue reaction excited by an aneurysm is a very formidable process, and lysis of a nerve from this scar becomes increasingly difficult with time. Thus an indication for early intervention may be to facilitate dissection, if the nerve be an important one. Because of the usually long operating time required to take care of the arterial injury, and because of the distortion of tissues and occasional infections, formal suture of nerves is seldom possible at the same time. Lysis is performed and, if the nerves are severed, lysis with simple approximation of the ends is done as a first stage procedure. Fibrin film has been used in several cases in the preparation of the bed for a subsequent formal neurorrhaphy.

Giving each man adequate care in a busy general hospital leaves little time for purely investigative research into the material at hand. Visualization of these arterial lesions by injection of diodrast (35%) is simple, however, and sometimes may be of direct assistance in their care. Injection of diodrast may be quite innocuous, but the observation has been made that fresh clot may be laid down in aneurysmal sacs following its use, although no thrombosis in the vessels themselves has occurred (2). Figure 1, a and b (Case 16), shows x-ray pictures of an arteriovenous aneurysm of the femoral artery and vein with

a large false sac. Although the profunda femoris artery was not visualized as had been desired (at operation it was found to have arisen above Poupart's ligament), the films gave other information: that little or no clot exists in the false sac; that the fistula is a comparatively large one; that the superficial femoral vein below the lesion is thrombosed. Figure 1, c and d, shows chest films from the same case. The preoperative film shows definite cardiac enlargement in 4 months' time. Figure 2 is a drawing kindly executed at operation by Mr. Edward Laning, at that time a patient in the hospital. In Case 9 a saphenous vein transplant was used to bridge a 3 centimeter defect between popliteal and posterior tibial arteries[1]. Circulation was very critical for a time after operation and early visualization by a potentially irritating solution was considered too risky. Accordingly, arteriography with diodrast was deferred until the 11th postoperative day. At this time (Fig. 3) the anastomotic channel was not patent, and how long the vein segment functioned is not known. But the importance of the longitudinally directed descending artery to the gastrocnemius over the small transversely placed geniculates is very apparent.

The case reports (Cases 10, 11, 12) on retroperitoneal pulsating hematomas speak for themselves. The lesion is a very dangerous one. To open into it, identify, and secure the vessel is a happy outcome which we have not experienced. At postmortem the vessel could not be found in either of the 2 fatal cases. The third patient, now 6 weeks after operation, has not bled; perhaps the fibrin foam played a part; perhaps the vessel was severed, with retraction of the ends during blind exploration with the finger. In any event an intra-abdominal mass with bruit would seem to be a sign to summon all one's courage, skill, and available blood stores.

The indications for operation upon these aneurysms fall into three groups. Under the first are included the emergency indications: hemorrhage, either external or internal; rapidly increasing tension in the sac with threatened bleeding; and insufficient circulation distally with threatened gangrene. Pressure from the expanding sac alone may bring about the latter condition. The second group includes cases with progressive nerve damage, or those cases in which it is assumed that dense scar is leading to irreparable nerve damage. The adequacy of collateral circulation must be fairly certain, of course, before surgery is attempted. Into the third group fall those operations done for cure of the aneurysm. These are done at the optimum time, when it is known that ligation will be safe. Plastic procedures to re-establish the main channel are not without danger and are not needed in elective cases. It has been found that 2 months is usually adequate for arterial ligation without risk of circulatory embarrassment in false aneurysms. Since these lesions are best treated by splinted rest prior to operation, longer immobilization may not be justified because of joint injury and muscular atrophy. In any event these patients should not be evacuated to the zone of the interior before operation because of the danger of hemorrhage in transit. Several of the patients seen here began to bleed while lying quietly in bed 2 months after formation of the "stable" aneurysm; and without the immediate availability of blood and an operating room, disaster might have occurred. In arteriovenous lesions probably 3 months is a better time interval prior to operation, since collaterals are probably slower to develop. Usually the cardiac load imposed by the fistula can be disregarded this long. These patients are safe to travel and after the lesion has reached stability (that is, the wound is healed and the mass remains stationary), they should be evacuated to the zone of the interior. Indications to operate upon them in the theater of operations consist in the presence of a large false sac as well (Case 16); or to improve circulation to a partially gangrenous part (Case 15); or to prevent increasing nerve paralysis (Case 14).

The operative technique is important. Even when possible the use of a tourniquet is not desirable since further trauma of any kind may add to spasm. It may be set in place, to

[1]This anastomosis was done over the specially constructed vitallium tubes designed by Blakemore *et al.* Some months previously Major Andrew McBride had demonstrated these tubes and had been waiting for a suitable case. Unfortunately, his hospital left the theater before this popliteal case came to us. The tubes used were secured, in a hurry, from Lt. Col. F. A. Simeone who assisted in the operation.

be tightened only if uncontrollable bleeding occurs. The incision must be direct but should take into consideration any known collateral vessels. It is of the utmost importance to expose and control the intact artery proximally and distally before dissection of the sac is begun. This step cannot be overemphasized. It is tempting to expose what seems to be a well formed sac; but too many times the wall of the sac is little more than an overlying anatomic structure. In Case 5, when the pectoralis major tendon was reflected, the "sac" was found to be open, the opening being 3 centimeters in diameter with clot protruding. The artery had been controlled earlier through normal structures just beneath the clavicle. No sac can be counted upon to be safely dissectable without this control; sudden unexpected bleeding leads to hurried clamping, and not only may collaterals be injured but nerves as well because of their proximity. Further, the rare chances of repair of the injury without ligation are lost. The proximal and distal vessels can be controlled well with simple rubber tubing of small diameter. The adventitia of the vessel may be injected with 0. 5 per cent novocain at the beginning to interrupt the perivascular nerves, a procedure which may help control spasm during the following manipulation. Dissection of the sac is usually a long and difficult job, complicated by nerves embedded in dense scar. In arteriovenous aneurysms, bleeding from multiple small dilated veins may be very troublesome. The electrocautery is useful.

If doubt exists as to the circulation of the part, the artery is temporarily occluded during dissection, and the effect on the hand or foot is noted. If the resulting circulation appears critical, the possibilities of some type of aneurysmorrhaphy or the insertion of Blakemore tubes are considered. It is not inconceivable that in certain cases the operation should be discontinued before opening or injuring the sac, and more time be allowed for collaterals to develop. Brisk bleeding from the distal end of an artery is proof that the collaterals are adequate.

At this point, the question of suture of an arterial rent, aneurysmorrhaphy, or anastomosis of vessels comes up. It is rarely possible to repair a hole, since it usually involves too much of the arterial circumference. One case (Case 1) was successful. Any plastic procedure entails the risk of thrombosis, embolism distally, or recurrence of the aneurysm. Hence ligation, preferably proximally and distally with excision of the sac, is the procedure of choice. Ligation is never done in continuity; and, of course, in arteriovenous aneurysms, ligation of the proximal artery alone is never done because of the resultant gangrene dependent upon the still patent fistula diverting the collateral blood before it reaches the critical distal bed. Quadruple ligation with excision or obliteration of the fistula must be done.

When dissection of the sac is complete it is excised. Both ends of the artery are ligated doubly, one being a transfixion suture. In the false aneurysm a segment of accompanying vein is resected, although a superficial perusal of the literature available here leads one to question the rationale of this procedure, despite Makins' findings from the last war. The wound is closed in layers tightly or with only superficial drainage in infected cases. Firm but not constrictive dressings are applied. No immobilization is necessary if no anastomosis or plastic procedure has been done; but associated nerve injuries, e.g. peroneal, may require splinting. If circulation is critical, the position of the part may be important. Slight dependency is indicated unless edema develops or increases. No external heat is used. Sympathectomy, if not performed prior to operation, may become necessary in the early or late postoperative period. Lower limb cases are allowed out of bed guardedly after 2 weeks and the effect of dependency is noted. Observation will determine the future course.

Holman has advocated exposure and control of the common and external iliac arteries prior to operations upon the femoral. This procedure has not seemed to be necessary in our patients. It has always been possible to get safely above the lesion through the same incision in our experience. Occlusion of the normal vessel close to the aneurysm allows the limb to receive its collateral blood during operation. Further, the same author, on the

basis of very convincing experiments, advocates resection of a major vessel up to the next large collateral in order to obliterate a blind pouch with consequent arterial pressure dissipation. Figure 3 shows the collateral vessel to the gastrocnemius assuming a very essential function; at operation this vessel was but a thread, and upon the basis of the criteria mentioned, might have been sacrificed. Classical main collateral channels are subject to so many anatomical variations (see Cases 6 and 7) that we do not believe that any vessel should be sacrificed. The size of the arterial branches can be very deceptive and spasm may completely conceal the importance of a vessel which is otherwise apparently insignificant.

The following case abstracts give only the barest essential data to illustrate the foregoing discussion.

CASE REPORTS

CASE 1. J. Z., false aneurysm of brachial artery. Repeated external hemorrhages through small puncture wound at elbow were controlled by pressure. Development of a pulsating hematoma. Emergency operation was done 2 weeks after injury for increase in size of the hematoma. A longitudinal rent behind the bifurcation of the brachial artery was sutured. Radial and ulnar pulses were good afterward and maintained. Returned to duty in 3 weeks.

This is the only case in which simple suture was possible and feasible.

CASE 2. A. K., false aneurysm of prima perforans branch of profunda femoris. A large red indurated mass of upper posterior thigh diagnosed as abscess was operated upon 6 weeks after wounding. Aspiration revealed the true state of affairs, but hemorrhage was immediate and severe and required control of the femoral artery quickly. Exposure and ligation of small, partially torn vessel were done. Bruit was not listened for prior to operation. Uneventful recovery.

CASE 3. D. M., false aneurysm of popliteal artery. Hemorrhage from débrided popliteal wound was noted on arrival at hospital from France 3 days after injury. Skin over space was secondarily closed and pressure dressing was applied. Three more hemorrhages occurred during next 5 weeks with development of mass and bruit. Further bleeding and emergency operation was carried out by Captain John Modlin. A perforated femoral artery was found (at popliteal junction) through and through wound, both holes patent. Resection of injured portion and ligation were done. Sympathectomy was done next day because of critical circulation; then uneventful recovery.

CASE 4. A. J. S., false aneurysm of third portion of axillary artery. Known radial and ulnar palsies with typical pulsating mass present in axilla. The wound was granulating. Presence of bloody discharge was noted on the 26th day after injury and was feared to be a sign of threatened hemorrhage. Operation was performed the next day. The nerves were identified (both severed), the sac was dissected out and excised. Proximal ligation was performed between anterior and posterior circumflex humeral vessels. The nerves were approximated. Circulation, tested during operation, was satisfactory postoperatively. Patient was sent to zone of interior for formal nerve repair.

CASE 5. H. S., false aneurysm of axillary artery. There was a slow increase in the size of the infraclavicular mass; at first it was diagnosed as a deep abscess with retained foreign body. Bruit appeared and operation was performed 8 weeks after injury. Although the radial pulse was good, operation was not postponed longer because of the increasing paralysis of the median and ulnar nerves. A small tear in the artery was found just proximal to the junction of the medial and lateral cords of the brachial plexus. There was free bleeding from the distal end of the vessel. The artery was divided and ligated, and a segment of vein resected. The medial cord and ulnar nerve were badly torn but still in continuity. Lysis of both nerves was done with fibrin film inserted about them. Course was uneventful. Patient sent to zone of interior for secondary nerve repair.

CASE 6. N. F., false aneurysm of femoral artery. A known false aneurysm of the thigh was under observation. It began to enlarge suddenly and rapidly 2 months after injury. Bed rest had been mandatory because of other injuries (fractures). Emergency operation under tourniquet was necessary; 0.5 centimeter tear in artery just proximal to adductor canal, with very large hematoma cavity (2000 c. c.). Artery and vein were resected and ligated. Sympathectomy was done next day because of critical circulation. There was excellent warmth of foot 3 days later. Subsequent course was uncomplicated.

CASE 7. M. M., false aneurysm of femoral artery. A known false sac of thigh was under observation. Increase in size was rather sudden with edema and paralysis of foot 5 weeks after injury. Emergency operation was done to repair a 0.7 centimeter slit in the artery just above the adductor canal, with 800 cubic centimeter cavity. Blakemore tubes were available, saphenous vein segment was removed, but not used because of technical difficulties. Excision of injured segment with ligation was performed. Accompanying vein was resected. Lysis of contused tibial nerve was carried out. Circulation was good; recovery uneventful.

Cases 6 and 7 are similar both as to the location of the injury and clinical course up to

operation. Note difference in circulation after operation.

CASE 8. D. H., false aneurysm of popliteal artery. There was a known false aneurysm in the popliteal space with edema of the foot. Sudden enlargement followed an attempt to get into a wheel chair, 4 weeks after injury. Swelling was controlled by pressure but edema increased and the mass enlarged into the calf. Emergency operation was done 2 days later with ligation and resection of a partly torn artery. The vein was resected and the contused tibial nerve lysed. Sympathetic block 1 hour after operation (pontocaine used as spinal analgesic wore off). Circulation was good, and there was a rapid subsidence of the edema. The wound was moderately infected.

CASE 9. S. V., false aneurysm of popliteal artery. The foot with very critical circulation was seen by us 3 days after injury; it was cold, pulseless, the calf was tense and there were complete paralysis and anesthesia to above the ankle. There was a bruit over the popliteal space. No treatment was given, in transit from the French invasion, to a small perforating popliteal wound. Since there was slight blanching of the nail beds, the leg was splinted and 1000 cubic centimeters of blood given. Twelve hours after admission a severe hemorrhage occurred from the medial wound, necessitating a tourniquet (25 minutes) and causing shock. Transfusion was again given. The foot was icy cold, blotchy, and the calf stony hard. There was no bruit. Operation was done 10 hours later (tubes not available until then): sympathectomy, resection of a length of saphenous vein, and anastomosis of the popliteal artery to the posterior tibial over Blakemore tubes and the vein segment, bridging a 3 centimeter defect. A functioning channel was obtained. No heparin was available. Lysis of contused tibial nerve was done and the wound partially closed. (Operating time, 2 hrs. 25 min.) There were several critical days, then good warmth and color. Secondary closure of the wound was done 7 days later. There was a slight ooze from the central portion of the wound on 14th day, which was thought to be from the superficial tissues. No bruit, mass, or further bleeding was present at follow-up 4 weeks after operation. Patient is not yet able to leave foot dependent. Diodrast study showed segment nonfunctioning on the 11th postoperative day.

(The missile had struck artery at the bifurcation. The posterior tibial had retracted beneath the gastrocnemius. Nothing was left of the anterior tibial except a thin strip of tissue from the anterior wall which, because still connected to the popliteal, held this vessel on the stretch and prevented it from retracting. The artery was thus found gaping widely at operation.)

CASE 10. J. B., false aneurysm of mesenteric vessel. Exploratory laparotomy was carried out with suture of the hole in the ileum and notation of retroperitoneal hematoma soon after wounding at front. A second laparotomy was done 1 week later at the same hospital, for intestinal obstruction due to a Richter's type hernia. He developed severe abdominal pain 10 days after this on a boat in transit to the base. On admission here, 17 days after wounding, both laparotomy wounds were clean and healing. There were a thrill and bruit over the 16 centimeter mass in the abdomen, presenting to left of the midline. Spontaneous rupture occurred next day with deep shock and rapid progress toward a moribund state. Immediate laparotomy was done under local anesthesia. A huge ill defined sac was present within the mesenteries. Patient died on the table, despite massive blood transfusions. The site of the vascular injury was not found at postmortem examination.

CASE 11. G. M., progressively enlarging hematoma of the retroperitoneal space. There was a sudden onset of severe abdominal pain 2 weeks after laparotomy at the front for a penetrating wound of the abdomen. Diagnosis of retroperitoneal hemorrhage was made but operation was postponed because of poor condition. Laparotomy was done 2 days later. There was a huge retroperitoneal hematoma on the right which on aspiration yielded dark, clotted blood. No thrill was felt. The process was believed to be stationary; the abdomen was closed. There was progressive difficulty after operation with pain, distention, then hematemesis, melena and hemoptysis prior to death. At postmortem examination extension of the hematoma was seen to have reached all mesenteries, and the whole retroperitoneal space was greatly ballooned out. The responsible vessel was not found.

CASE 12. R. M., progressively enlarging hematoma of retroperitoneal space. There was a penetrating wound of the pelvis through the sciatic notch. The abdomen was not explored at front. Three weeks later a large mass was discovered palpable both rectally and abdominally, accompanied by fever, symptoms of mild obstruction. A shell fragment 1.5 centimeters in diameter was present in the area. Laparotomy was done for a suspected abscess, which was found to be a hematoma by aspiration. The mass was opened transabdominally with immediate profuse bleeding controlled by pressure on the right hypogastric artery. This vessel was exposed, divided, and ligated. The clot and foreign body were removed; followed by recurrence of bleeding from deep within pelvis. Only control possible was fibrin foam and large gauze pack soaked in thrombin. The pack was left in for 5 days then removed. There had been no recurrence of hemorrhage at 5 weeks.

CASE 13. W. D., arteriovenous aneurysm of popliteal artery. A typical arteriovenous aneurysm of the popliteal artery with fistula into a subsidiary vein, and false sac 6 centimeters in diameter were noted. There was a bradycardiac reaction of 20 beats per minute upon obliteration of the fistula. Patient was allowed to be ambulatory and observed for 8 weeks. Elective repair consisted of excision of

the sac and fistula, quadruple ligation, and resection of a segment of the popliteal vein. Sympathetic block was done once after operation. Course was uneventful. Five months' follow-up; from patient: "hiking 20 miles a day without difficulty. Coming back overseas."

CASE 14. R. C., arteriovenous aneurysm of the axillary artery and vein. A typical arteriovenous lesion with sac 4 centimeters in diameter presented beneath the clavicle. Patient observed for 6 weeks and operated upon 2 months after injury because of progressive ulnar paralysis. Transection and medial retraction of the inner two-thirds of clavicle (giving excellent exposure without resection of this bone), proximal and distal exposure and control of vessels, dissection of the sac, fistula, and plexus, with lysis of the ulnar nerve were done. Excision quadruple ligation. The clavicle was reunited by means of a 4 centimeter length of Kirschner wire forced into the marrow cavities (no constricting shoulder dressing was desired postoperatively). Uneventful recovery. Patient sent to zone of interior because of associated injuries (severe hemothorax).

CASE 15. J. A., arteriovenous aneurysm of superficial femoral artery and vein. Patient entered hospital 4 days after injury, with hard calf, edematous foot, and beginning gangrenous demarcation of toes. There were small puncture wounds of both the femoral and popliteal areas; no pulsations. Sympathetic blocks on two occasions were thought to have softened the calf slightly. An arteriovenous lesion of the femoral vessels 5 centimeters below Poupart's ligament was discovered by the patient 5 weeks after injury. Sympathectomy was done followed by excision of the fistula and quadruple ligation 7 days later. (No false sac.) Recovery was uneventful. The circulation to the lower leg was definitely better immediately following closure of the fistula as it had also been after sympathectomy. Prior to evacuation simple guillotine amputation just above the ankle was done. It was felt that the operations might have saved a portion of the lower leg.

CASE 16. W. H., arteriovenous aneurysm of the femoral vessels. A typical lesion with the large false sac illustrated in Figure 2. There were no symptoms and the sac was discovered quite accidentally during a routine check of patient's healed wounds 3 months after injury. Sympathectomy was followed in 7 days by complete excision of the sac and fistula and quadruple ligation. Patient was walking in 10 days. The lesion was operated upon in this theater because of the large size of the false sac and possibility of rupture.

The remaining 6 cases of arteriovenous aneurysm were evacuated to the zone of the interior for treatment. Their lesions seemed perfectly stable, and it was not justifiable to wait out the observation period overseas. The single patient with false aneurysm who was sent home unoperated upon had a subclavian lesion of small size which, after a month's observation, became even smaller.

Cases 1, 4, 8, 13, and 14 have been previously reported in detail (3).

TABLE I.—ANALYSIS OF MATERIAL

False aneurysms	
Total cases	20
Major vessels	10
Minor vessels	7
Retroperitoneal cases	3
Associated nerve lesions all major cases	6
Total number operated upon	19
Hemorrhage as indication	12
Nerve lesion as indication	2
Early elective ligation, nonessential vessels	5
Gangrene	0
Deaths (both in retroperitoneal group)	2
Arteriovenous aneurysms	
Total aneurysms (2 in one case)	10
Major vessels	10
Associated nerve lesions	3
Number operated upon	4
For hemorrhage	0
For increasing nerve injury	1
For danger rupture of sac	2
To improve circulation distally	1
Gangrene (established on admission)	1
Deaths (unrelated brain abscess)	1

SUMMARY AND CONCLUSIONS

Observations on 30 patients with aneurysms (20 false, 10 arteriovenous) are presented. On the basis of these cases, the following conclusions are drawn:

The tendency of false aneurysms to bleed unexpectedly and profusely is so marked that in such cases operation should be carried out before evacuation to the zone of the interior, even if a period of several months' observation is required before ligation can be performed safely.

On the other hand patients with arteriovenous aneurysms are much more stable, do not tend to bleed, require a longer observation period, and can be evacuated safely to the zone of the interior unless some indication exists for early surgery, such as, for example, an additional large false sac or increasing nerve damage.

"Aneurysms" of the retroperitoneal space are serious lesions and will require the surgeon's utmost skill to achieve success.

Aneurysms may simulate abscess so closely that alertness must be practiced. Aspiration

should be done at the time of operation if any doubt exists.

Classical channels of collateral circulation are extremely variable. No vessel, however small, should be sacrificed deliberately. Spasm may obscure the importance of an apparently insignificant arterial branch.

If any doubt of adequacy of circulation exists, operative sympathectomy should be performed. Sympathetic block with novocain is temporary and cannot be relied upon in all cases; it should be reserved for those instances only in which additional surgery cannot be tolerated.

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PENICILLIN THERAPY IN ACUTE OSTEOMYELITIS

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THE management of acute osteomyelitis has been unsatisfactory and the results uncertain. Diagnosis has been difficult and the disease has often been unrecognized until extensive destruction of bone occurred. Even when early diagnosis was made and surgical drainage instituted early, a chronic suppurative process usually followed, characterized by draining sinuses, sequestration, local formation of greatly thickened and eburnated new bone, soft tissue abscesses, and recurrent acute exacerbations. Although the original infection became greatly attenuated in time, sinuses often persisted and discharged pus intermittently for years. Sequestrectomy or saucerization of chronically infected bone usually produced healing, but offered no guarantee against recurrences. Too frequently the disease appeared to be cured only to flare-up after a period of months or many years. The illness has been commonly seen in childhood and the chronicity of the process required long periods of treatment which removed the child from school and physical play. For these reasons and the uncertainty of the outcome, permanent personality changes became engrafted upon other sequelae of the disease such as limp, deformity, or ankylosis of adjacent joints.

Chemotherapy with sulfonamides used in association with timed surgical intervention aided in the management but left much to be desired.

In March, 1943, Florey had prophesied that one might anticipate the time when osteomyelitis, treated early and intensively with penicillin, would not require surgical intervention.

MATERIAL

During the past 21 months we have observed the results of treatment in 34 cases of acute osteomyelitis with penicillin (Table I).

From the Department of Surgery of the University of Cincinnati College of Medicine and Cincinnati General Hospital. The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the University of Cincinnati.

In the group there were 25 cases of acute hematogenous osteomyelitis of the major long bones, some of which also had involvement of the flat bones of the pelvis. In addition there were 3 cases with infection of the pelvic bones only, 5 of the facial and cranial bones, and 1 of the ribs. In 13 instances the process involved two or more bones simultaneously. The ages of 30 of the cases were in the first three decades of life illustrating again the prevalence of the disease in the young. Nine of the patients were females and 25 were males, a fact emphasizing the higher incidence of the disease in the male. The portals of entry of the hematogenous infection were apparently the pharynx or nasopharynx in 5 instances, furuncles or other localized skin or wound infections in 8 instances, and unknown in the remainder. Two of the patients had diabetes mellitus, 1 had rickets in addition to the acute bone infection. The responsible etiologic agent was determined in every instance but 1, and was found to be the hemolytic Staphylococcus aureus in 29 cases, the nonhemolytic Staphylococcus albus in 2, the Streptococcus hemolyticus in 1 and the pneumococcus type III in 1. In 6 instances the nonhemolytic streptococcus was found in the pus in association with the hemolytic Staphylococcus aureus. Detailed bacteriologic examinations were made of the blood in all patients and of the pus in 21 of the cases. Positive blood cultures were obtained in 20 of the cases, the Staphylococcus aureus being recovered in 19 instances, and the pneumococcus type III in 1. The nonhemolytic streptococcus was found in association with the hemolytic Staphylococcus aureus in 2 cases.

METHOD

The administration of penicillin was regarded as the primary treatment of each case and every effort was made to observe the full effect of this single agent before any change was made in the therapeutic regimen, although it was not always possible to follow this procedure.

TABLE I.—RESULTS OF PENICILLIN IN 34 CASES

No.	Age	Sex	Bones involved	Bacteriemia	Bacteria				
					H.S.A.	N.H.S.A.	H.S.	N.H.S.	Pneu.
1	24	F	Parietal	No	+				
2	12	F	L. frontal	Yes	+				
3	1	M	L. fibula	No	+				
4	13	M	R. femur, L. tibia and fibula	Yes	+				
5	5	M	L. tibia	No	+				
6	10	M	R. tibia	Yes	+				
7	5	F	R. femur, L. tibia	Yes	+				
8	46	M	R. tibia, 6th rib	Yes		+			
9	40	F	Mandible	No	+			+	
10	17	M	L. acetabulum, L. humerus. lumbar vertebra	Yes	+				
11	25	F	Parietal, temporal and occipital	No		+		+	
12	31	M	L. humerus	No	+			+	
13	11	M	L. femur and acetabulum	No	+				
14	21	M	L. pubis, ischium	Yes	+				
15	14	M	R. sacroiliac area	No	None identified				
16	5	M	R. femur, acetabulum, R. pubis, ischium	No			+		
17	4	F	R. tibia	Yes	+				
18	2 mo.	M	L. femur	Yes					+
19	8	M	R. pubis, ramus	Yes	+			+	
20	6 mo.	M	R. 6th and 7th ribs	No	+			+	
21	8	M	L. humerus	No	+				
22	3	M	R. radius, ulna	No	+			+	
23	3	M	Maxilla	Yes	+				
24	15	M	L. femur	Yes	+				
25	21	F	L. acetabulum and femur	Yes	+				
26	33	F	L. femur, L. ilium	Yes	+				
27	13	M	L. humerus	Yes	+				
28	15	M	L. tibia	Yes	+				
29	2	M	L. tibia, fibula	No	+				
30	6	M	R. tibia	Yes	+				
31	21	M	R. tibia	No	+				
32	8	F	L. humerus	Yes	+				
33	12	M	L. humerus	Yes	+				
34	9	M	R. tibia	Yes	+				

H.S.A., Hemolytic Staphylococcus aureus
N.H.S.A., Nonhemolytic Staphylococcus albus
H.S., Hemolytic streptococcus
N.H.S., Nonhemolytic streptococcus
Pneu., Pneumococcus

Solutions of the sodium salt of penicillin in sterile physiological saline with a concentration of 5000 units per cubic centimeter were used in all but 1 case in which the calcium salt was employed. Care was taken to keep the solutions refrigerated at all times. The solution was administered by continuous intravenous drip in 10 cases and by interval intravenous or intramuscular injection in the remainder (Table II). The length of the interval usually was 3 hours but varied from 2 to 4 hours depending upon the severity of the in-

TABLE II

Penicillin Therapy					Surgical Intervention			
No.	Dose	Route	Time interval	Total dose	None	I & D	Osteotomy	Sequestrectomy
1	5,000	Topical	4 hrs.	375,000	−	−	+	−
2	10,000	I.V., I.M.	4 hrs.	300,000	−	+	+	−
3	15,000 10,000	I.M.	3 hrs.	634,000	+	−	−	−
4	25,000 15,000	I.V., I.M.	3 hrs.	728,000	+	−	−	−
5	10,000	I.M.	3 hrs.	530,000	+	−	−	−
6	15,000	I.V.	½ and 3 hrs.	120,000	+	−	−	−
7	50,000	I.V.	Continuous drip	433,000	−	+	−	−
8	40,000	I.V.	Continuous drip	300,000	−	+	+	−
9	30,000	I.V.	Continuous drip	270,000	+	−	−	−
10	30,000 100,000	I.V. I.V.	Continuous drip	555,000	+	−	−	—
11	30,000	I.V.	Continuous drip	510,000	−	+	+	−
12	40,000	I.V.	Continuous drip	260,000	−	+	+	−
13	40,000	I.V.	4 hrs.	432,500	−	+	−	−
14	40,000	I.V.	Continuous drip	280,000	+	−	−	−
15	15,000	I.V.	3 hrs.	885,000	+	−	−	−
16	40,000	I.V.	Continuous drip	640,000	−	+	−	−
17	15,000	I.M.	3 hrs.	1,365,000	−	+	−	−
18	10,000	I.V., I.M.	3 hrs.	410,000	−	+	−	−
19	15,000	I.V., I.M.	3 hrs.	2,090,000	−	+	−	−
20	10,000	I.M.	3 hrs.	1,225,000	+	−	−	−
21	10,000	I.M.	3 hrs.	950,000	+	−	−	−
22	10,000	I.M.	3 hrs.	1,160,000	+	−	−	−
23	15,000	I.M., I.V.	4 hrs.	140,000	−	+	−	−
24	10,000	I.M.	3 hrs.	925,000	+	−	−	−
25	50,000	I.V.	Continuous drip	410,000	−	+	−	−
26	40,000	I.V.	Continuous drip	420,000	−	+	−	−
27	15,000 10,000	I.M. I.M.	3 hrs. 3 hrs.		+	−	−	−
28	15,000	I.M.	3 hrs.	2,430,000	+	−	−	−
29	15,000 10,000	I.M.	3 hrs.	2,775,000	−	+	−	−
30	15,000 10,000	I.M.	3 hrs.	1,500,000	+	−	−	−
31	15,000	I.M.	3 hrs.	1,500,000	−	+	−	−
32	15,000	I.M.	3 hrs.	1,205,000	−	+	−	−
33	15,000	I.M.	3 hrs.	1,555,000	+	−	−	−
34	15,000	I.M.	3 hrs.	1,625,000	+			

fection, duration of treatment, and the supply of penicillin. The dose given by the interval injection varied between 5,000 and 25,000 Oxford units, and the usual dose at the start of treatment was 15,000 units. In severe infections 25,000 units were given every 2 hours for the first 3 to 6 doses. In those patients receiving penicillin intravenously by continuous drip, 30,000 to 80,000 units in 2000 cubic centimeters of physiological saline solution were

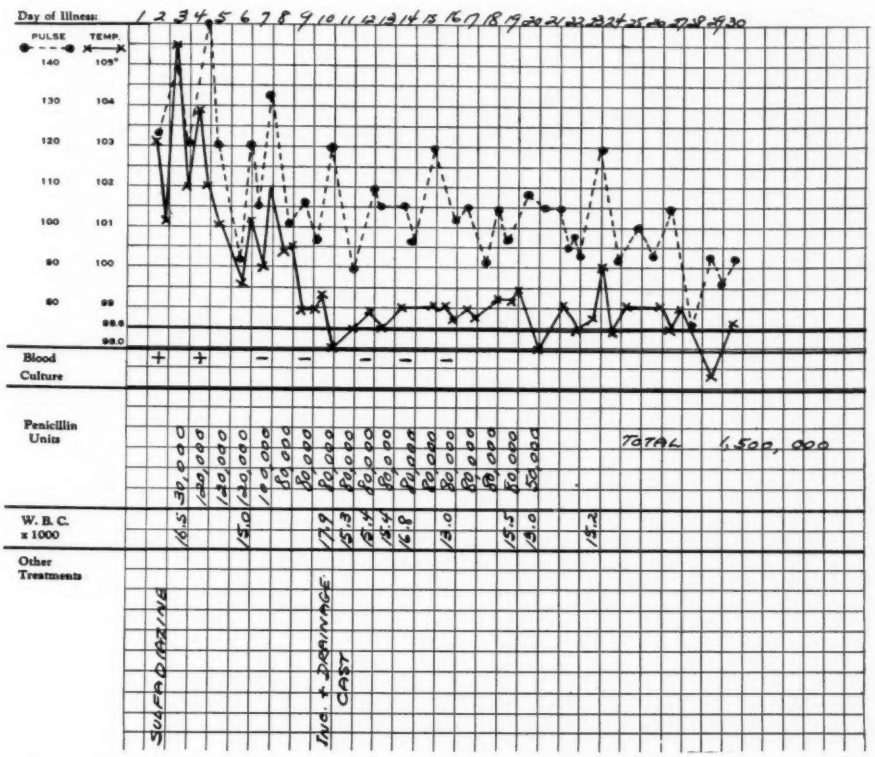
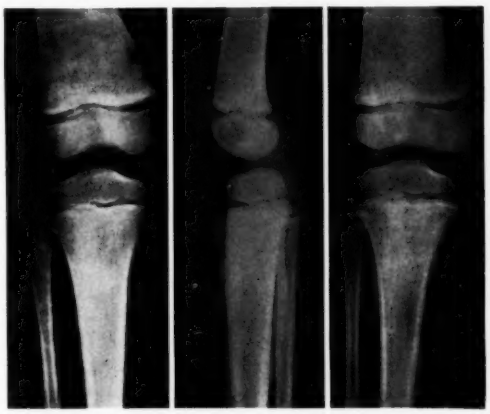


Fig. 1. Diagnosis: (1) Acute hematogenous osteomyelitis of left femur. (2) Staphylococcus aureus bacteriemia.

administered at the rate of 25 to 30 drops per minute. The dose was decreased when it was apparent that the infection was well controlled. In several of the earlier cases only 140,000 to 500,000 units were received as the total dose, which should probably be considered an inadequate amount. Experience has shown that a dose of 1,500,000 or more units administered over a period of 2 or more weeks is a desirable dosage.

As small soft tissue abscesses developed, they were aspirated with syringe and needle and partially filled with a solution of penicillin containing 5000 units per cubic centimeter every 2 or more days. In neglected cases with large abscesses, incision and drainage was carried out after adequate preoperative preparation. In 3 instances topical application was effected by dressings saturated with penicillin



June 6, 1944. August 5, 1944.

Fig. 2. B. S. Case 17.

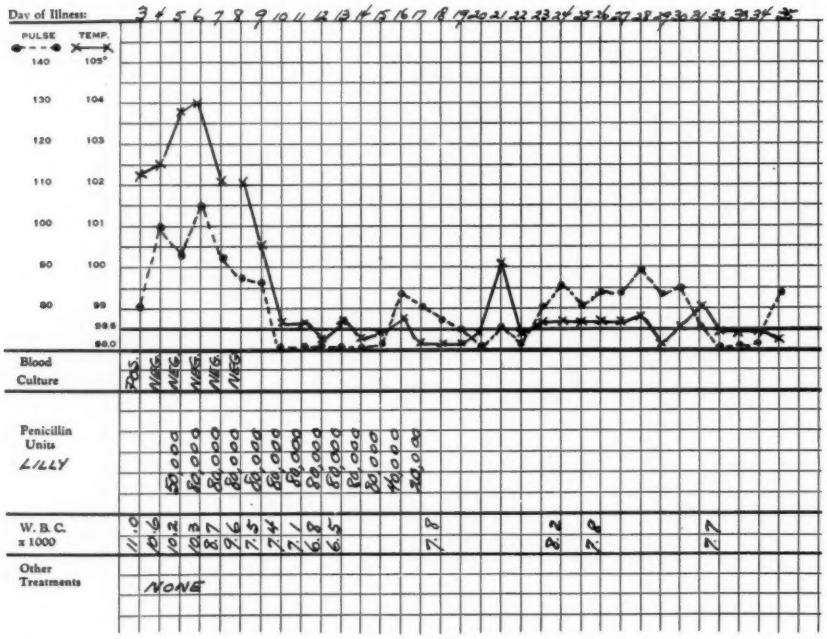


Fig. 3. Diagnosis: (1) Acute hematogenous osteomyelitis of left femur. (2) Staphylococcus aureus bacteriemia.

solution. In 1 case penicillin solution was also injected directly into the pericardial sac after that space had been emptied of its fluid accumulation by aspiration.

Plaster casts were applied in approximately one half of the cases for contrast with those treated without immobilization. Twenty-five of the patients had received sulfonamide therapy before penicillin was started and the remainder had not. Penicillin and sulfadiazine were given concurrently in 9 instances.

The case records of 10 illustrative cases of acute hematogenous osteomyelitis of the long bones which were treated with penicillin are reported. They have been grouped for purposes of discussion.

July 12, 1944. July 19, 1944. August 1, 1944.

Fig. 4. W. P. Case 24.

CASE 17. B.S., a 4 year old white girl, was admitted to the Children's Hospital on June 5, 1944. Two weeks before she had developed a blister on her heel which became infected and 2 days before, she complained of pain in the right leg and fever. She was placed on general sulfadiazine therapy and was allowed to return home. The symptoms increased progressively, requiring her admission to the hospital.

Examination showed a dirty, severely ill, white girl with marked swelling, tenderness, and local heat above and below the right knee. On the right heel there was a healing infected vesible.

The white blood count was 16,500 cells per cubic millimeter with 79 per cent polymorphonuclear leucocytes. The blood culture was positive for the hemolytic Staphylococcus aureus on June 5 and 7, 1944.

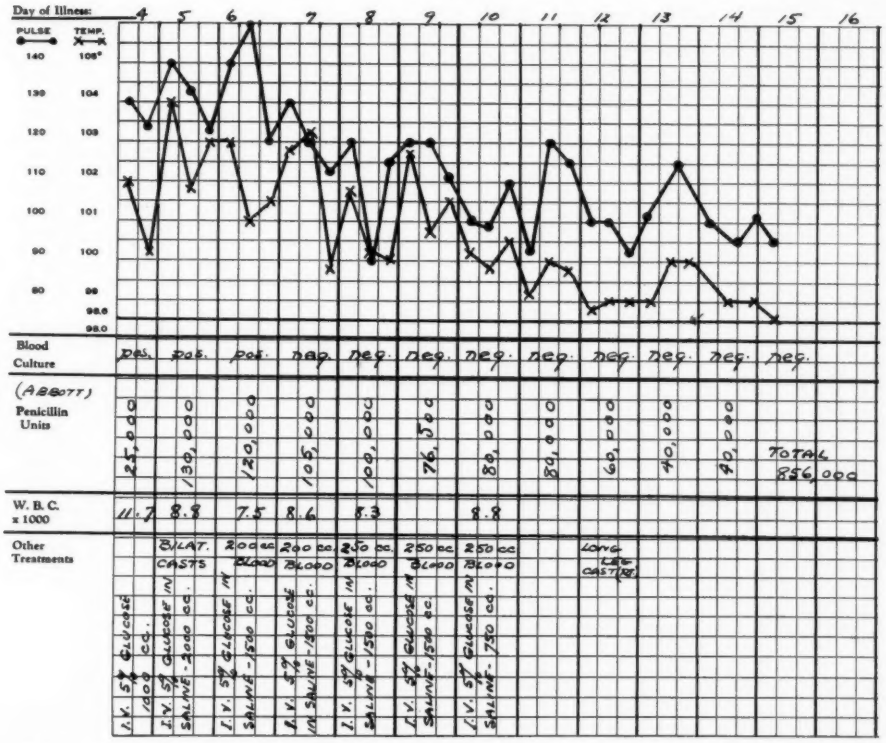


Fig. 5. Diagnosis: (1) Acute hematogenous osteomyelitis of right femur and left tibia. (2) Staphylococcus aureus bacteriemia. (3) Staphylococcal pneumonia.

October 26, 1943. November 17, 1943. January 4, 1944. March 31, 1944. June 2, 1944. September 1, 1944.

Fig. 6. K. M. Case 4.

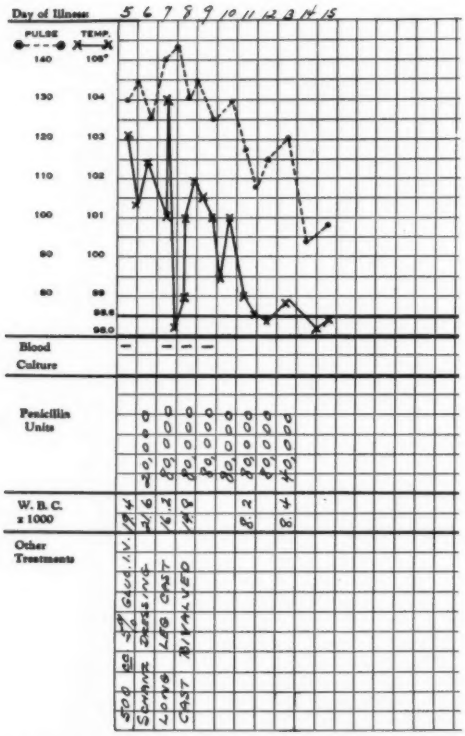


Fig. 7. Diagnosis: Acute hematogenous osteomyelitis of left tibia.

The patient was placed on parenteral penicillin therapy, 15,000 units being given every 3 hours at the beginning of treatment and 10,000 units at the same interval later (Fig. 1). A small fluctuant area developed over the upper end of the tibia and this was aspirated on June 11, 1944. Thin, watery pus containing the hemolytic Staphylococcus aureus was obtained. Two days later this abscess was incised, thus liberating a considerable amount of similar purulent material, and the leg was immobilized in a plaster cast. During the course of illness two transfusions were given and a new cast was applied on July 26, 1944. Progress roentgenograms have shown thickening of the periosteum over the lower third of the right femur and upper third of the right tibia (Fig. 2). The patient has made an excellent clinical recovery without recurrence to date.

CASE 24. W. P., a 15 year old white boy, was admitted to the General Hospital on July 10, 1944, complaining of a boil on his right elbow and pain in his left knee of 3 days' duration. About the time the lesion on the elbow appeared, he had sustained an injury of his left knee which produced a limp and moderate limitation of flexion and extension of the leg. There had been disability of the left knee following an injury in 1941.

Examination showed a drowsy and acutely ill adolescent boy, whose temperature was 103.2 degrees. F. Swelling, redness, tenderness, and increased local heat were present over the lower medial aspect of the femur. Pain and limitation of motion were associated with flexion of the knee. A small superficial furuncle draining pus was present at the right elbow.

The red blood count was 5,000,000 cells per cubic millimeter and the white blood count was 11,000 with 70 per cent polymorphonuclear leucocytes.

November 18, 1943. December 1 1943. December 13, 1943. Feb. 11, 1944. May 5, 1944. August 25, 1944.

Fig. 8. M. T. Case 5.

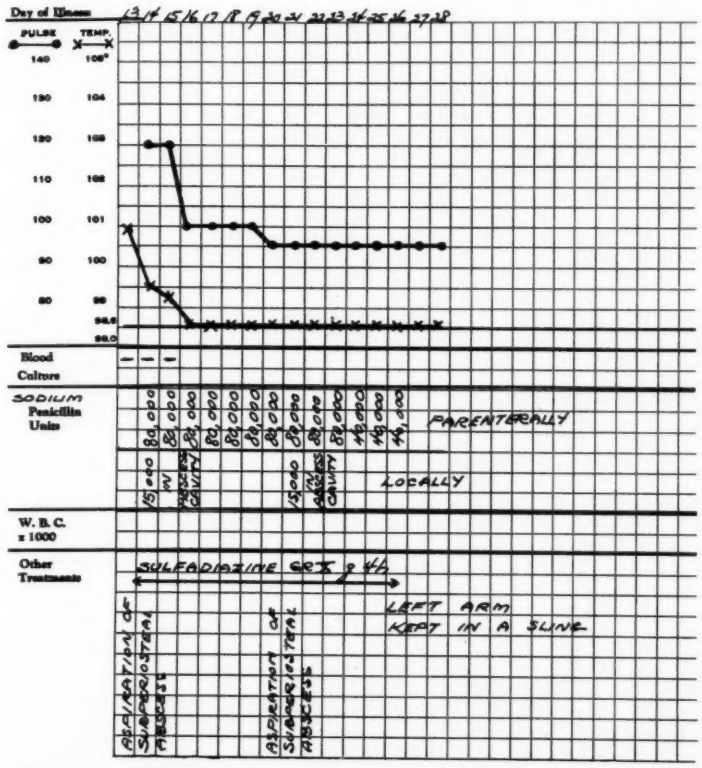
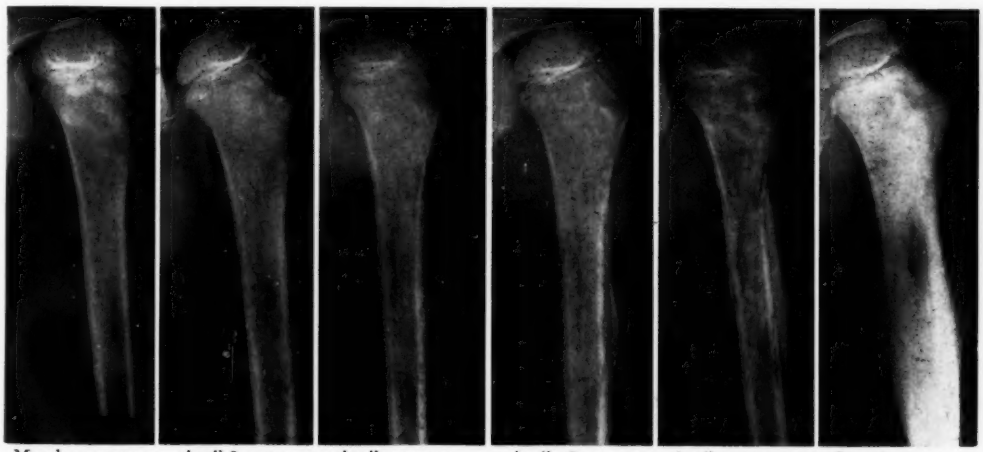


Fig. 9. Diagnosis: Acute hematogenous osteomyelitis of left humerus with soft tissue abscess.



March 31, 1944. April 8, 1944. April 12, 1944. April 18, 1944. April 27, 1944. June 22, 1944.

Fig. 10. R. S. Case 21.

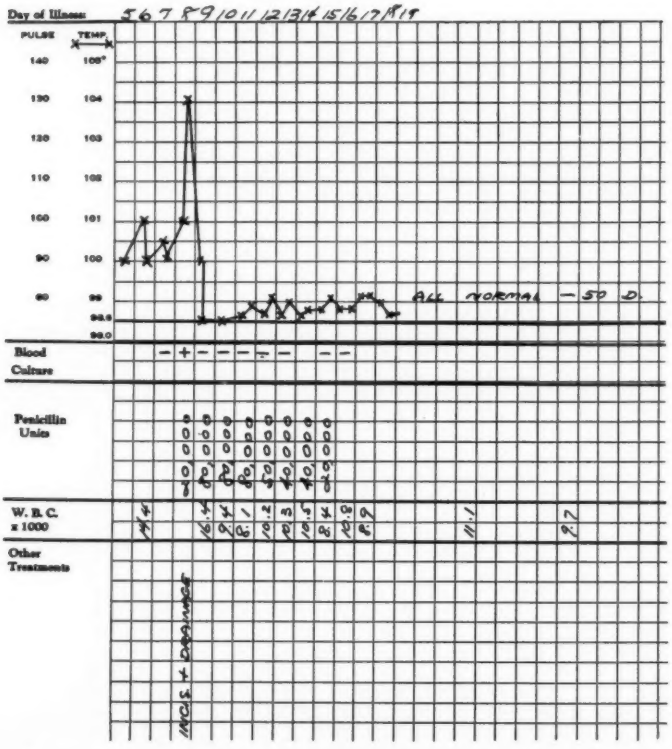


Fig. 11. Diagnosis: (1) Acute hematogenous osteomyelitis of femur. (2) Pneumococcus (type III) bacteriemia.

March 6, 1944. March 21, 1944. April 5, 1944. May 17, 1944. June 30, 1944. September 14, 1944.

Fig. 12. W. S. Case 18.

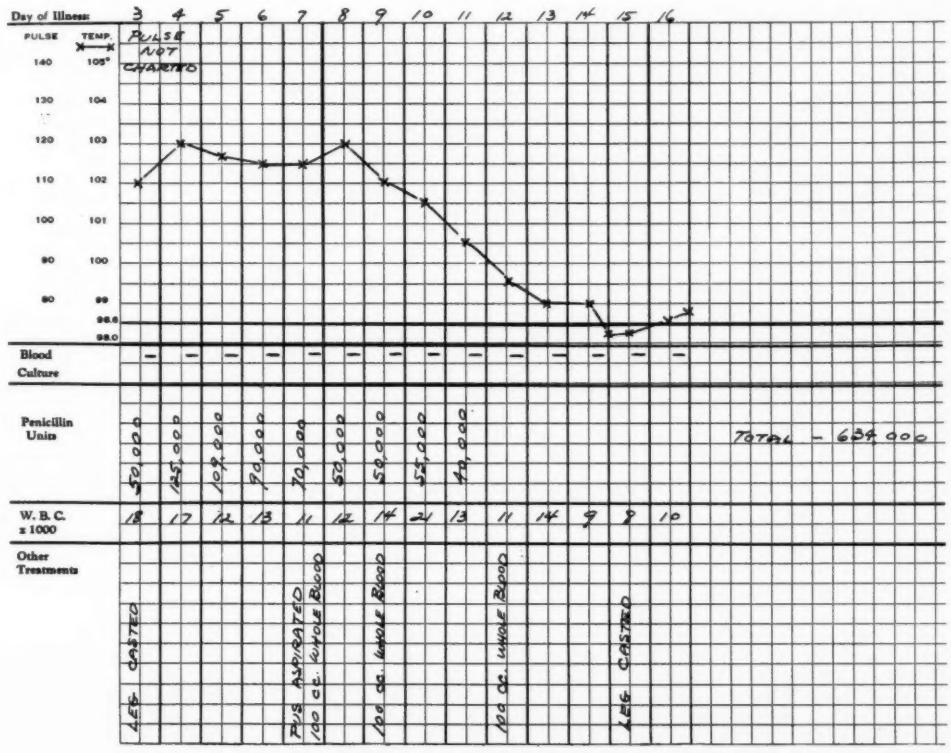
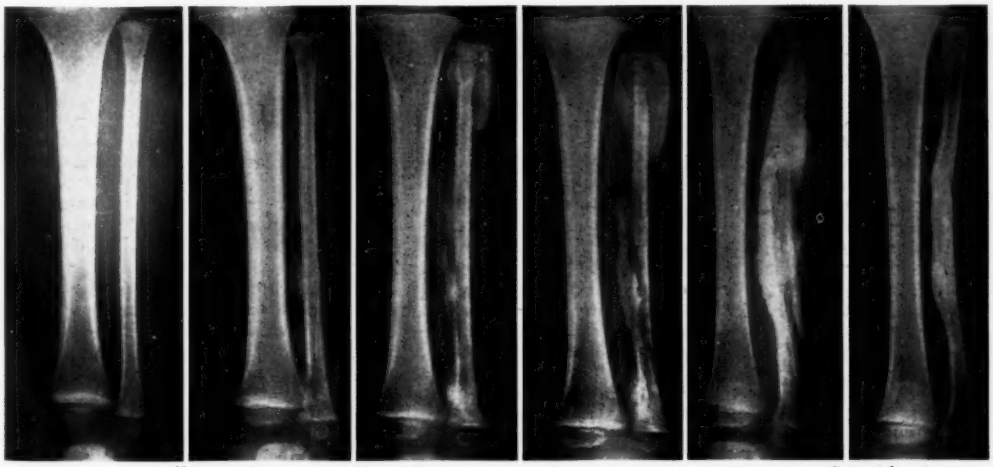


Fig. 13. Acute hematogenous osteomyelitis of left tibia and fibula.



October 23, 1943. November 4, 1943. November 15, 1943. Nov. 25, 1943. April 24, 1944. September 8, 1944.

Fig. 14. J. C. Case 3.

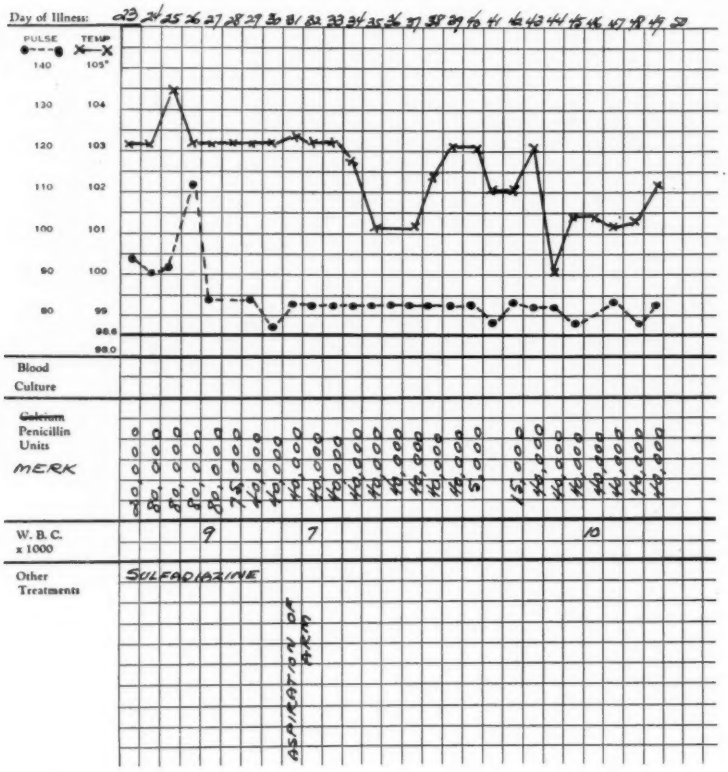


Fig. 15. Diagnosis: Acute hematogenous osteomyelitis of radius and ulna.

Cultures of the blood showed numerous colonies of hemolytic Staphylococcus aureus.

A few hours after admission he had a shaking chill and the temperature rose to 104.8 degrees F. Penicillin therapy was started on the third hospital day, 10,000 units being given intramuscularly every 3 hours for 10½ days and 5000 units at the same interval for 2 more days (Fig. 3). At this time there was suggestive roentgenological evidence of early osteomyelitis of the distal end of the femoral metaphysis and 7 days later the findings were definite.

Local treatment consisted of elevation and rest of the left thigh with no attempt to immobilize.

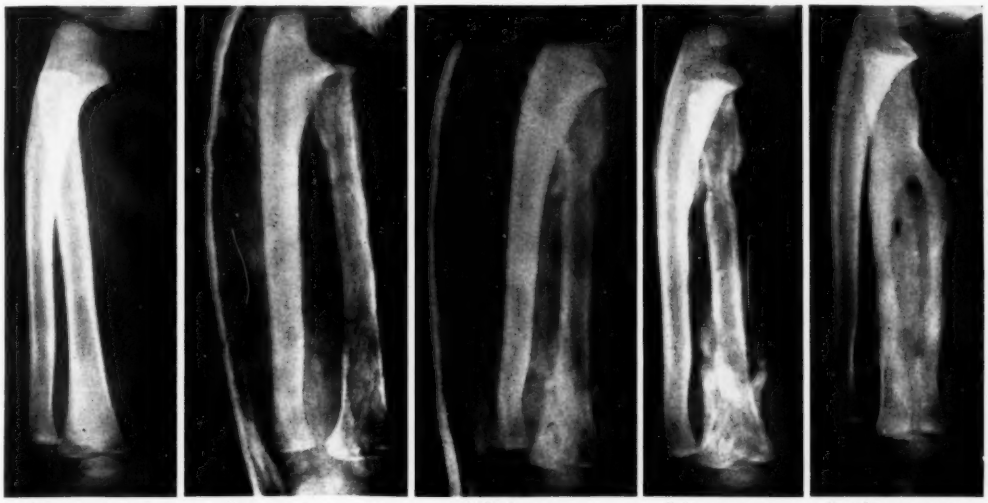
The temperature remained elevated for 60 hours and then fell rapidly reaching normal 3 days later. Disappearance of the local signs of inflammation about lower end of femur followed the fall in temperature. Later roentgenograms showed minimal residual bone lesions consisting of periosteal reaction and an underlying small area of demineralization (Fig. 4).

He was discharged on his 32d hospital day without sign or symptom of infection in the leg. As a precaution, crutches were used to delay active weight bearing. Since leaving the hospital he has remained in good health and without complaint.

CASE 4. K. M., a 13 year old white boy, was admitted to the Children's Hospital on October 26, 1943, complaining of pain in his left ankle and right knee. A furuncle had been present on the left elbow for 1 week. Five days before admission he turned his left ankle while playing. The following day he had a shaking chill followed by fever and malaise. Pain and swelling developed in the left ankle and 24 hours later the same changes appeared in the right knee.

Examination showed an acutely and severely ill boy whose temperature was 102.5 degrees F. A large furuncle was present on the left elbow and numerous petechiae covered the trunk and extremities. Many râles were heard throughout both lungs. About the left ankle and the lower half of the left leg there was increased heat, marked swelling, and exquisite tenderness. There was limitation of motion of the right knee with swelling and tenderness over the lower medial aspect of the right thigh.

The red blood count was 4,300,000 cells per cubic millimeter and the white blood count was 11,750



June 20, 1944. June 29, 1944. July 8, 1944. July 15, 1944. October 27, 1944.

Fig. 16. R. J. Case 22.

cells with 79 per cent polymorphonuclear leucocytes. Urinalysis showed the presence of acetone and a trace of albumin. Blood cultures were positive for the hemolytic Staphylococcus aureus. Roentgenograms suggested periosteal involvement of lower anterior aspect of left tibia. Changes in upper lung fields suggested acute embolic pneumonitis.

Penicillin was started on the first hospital day. After 2 doses of 25,000 units he was given 15,000 units intravenously every 3 hours. Three and one-half days later the dose was reduced to 10,000 units and 4 days later to 5000 units. It was discontinued on the 12th hospital day. Both legs were supported in long casts which were bivalved. There was no surgical intervention. Little response to penicillin therapy was evident for 72 hours (Fig. 5). The temperature remained high, the blood cultures remained positive and the signs of local inflammation persisted. Following this the fever gradually fell and reached 99 degrees F. on the 12th day after the start of penicillin therapy where it remained until the 27th hospital day.

On November 17, 1943, the roentgenograms showed periosteal elevation along the medial aspect of the distal end of the right femur and the lower third of the left tibia. He was discharged from the hospital on November 24, 1943, his 30th hospital day, with no clinical evidence of active infection.

On January 4, 1944, the periosteal reaction was more marked and areas of decreased density were seen in the right femur and left tibia (Fig. 6).

The casts were removed the first week in March and he was allowed to resume activity gradually. On March 3, 1944, there was increased mottling along the femoral shaft proximal to the right knee and in the lower end of the left tibia but the periosteal reaction had decreased. On June 2, 1944, recalcification was apparent suggesting that healing was taking place. The last films on September 1, 1944, showed further calcification and improvement; clinical examination showed no abnormality.

CASE 5. M. T., a 5 year old white boy, was admitted to the Children's Hospital on November 18, 1943, complaining of pain in the left ankle of 5 days' duration and fever. Three days before admission, sulfathiazole therapy had been started by his physician.

Examination showed an acutely ill, listless, irritable boy whose temperature was 103.2 degrees F. There was an exquisitely tender swelling of the left ankle which extended from the toes to the upper third of the leg. An area of fluctuation was detected in the region of greatest swelling and tenderness.

The red blood count was 3,750,000 cells per cubic millimeter and the hemoglobin determination was 10.7 grams. The white blood count was 12,100 cells with 89 per cent polymorphonuclear leucocytes. The urinalysis was essentially negative except for the presence of acetone. Blood cultures taken daily for 5 days were all reported as negative.

Penicillin therapy was started on the 2d hospital day, 10,000 units being given intramuscularly every 3 hours for 6 days. On the 7th day 5000 units were given every 3 hours. During this period the leg and foot were splinted in a Schantz dressing, but no surgical procedure was performed. His temperature had fallen to normal by the 6th hospital day (Fig. 7). The signs of inflammation about the left ankle regressed rapidly, the white blood count fell to normal, and his general appearance and behavior suggested that the infection had been promptly controlled.

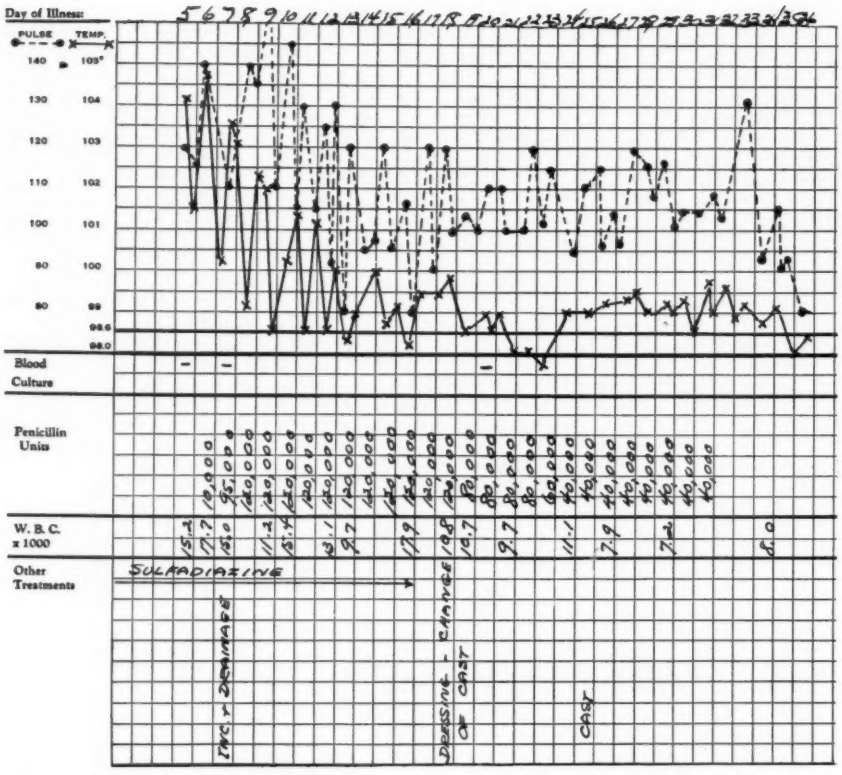


Fig. 17. Diagnosis: (1) Acute hematogenous osteomyelitis of left tibia and fibula. (2) Pyarthrosis of left ankle joint.

Roentgenologic examination at the time of admission showed no change in bone or joint of the left lower leg but on December 1, 1943, periosteal thickening was evident along the tibial shaft (Fig. 8). The periosteal thickening had increased and there was slight decrease in density in the lower end of the tibia just above the epiphysis by December 12, 1943.

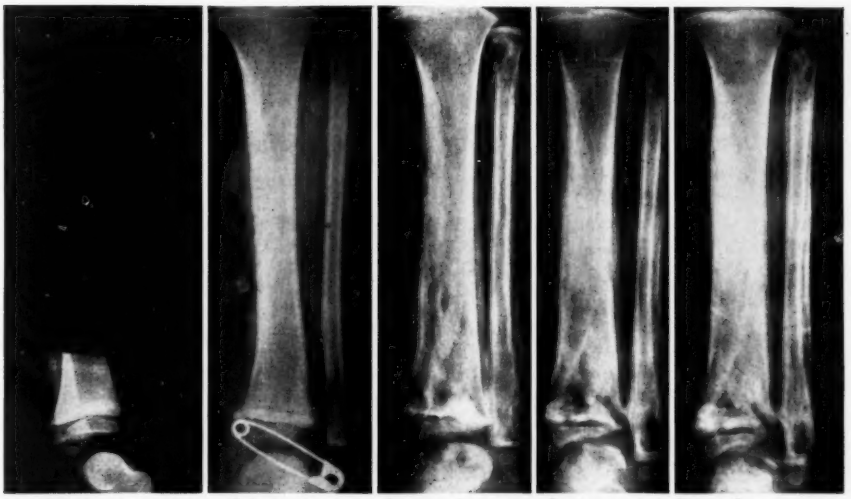
A long leg cast was applied on December 15, 1943, and he was discharged one day later, his 28th hospital day. Roentgenograms on February 11, 1944, showed numerous areas of decreased density in the metaphyseal area. On May 5, 1944, recalcification was evident on roentgen examination, and there was no clinical evidence of residual infection except slight stiffness in the left ankle. On August 25, 1944, the roentgenograms indicated that the infection had remained arrested and that further recalcification of the rarefied areas had occurred.

CASE 21. R.S., an 8 year old white boy, was admitted to the Cincinnati General Hospital on March 27, 1944, complaining of a painful swelling in the left shoulder and elbow. He had had a tonsillectomy on March 3, 1944 and several days later he developed pain in the left elbow and fever. Four days before admission, pain occurred in the left shoulder.

On examination his temperature was 103 degrees F. The sclerae were icteric. There was a loud systolic murmur at the apex. Extending from the left shoulder to the elbow there was a hot, reddened, edematous area which was exquisitely tender. Limitation of motion of both elbow and shoulder was present.

The white blood count was 18,700 cells per cubic millimeter with 80 per cent polymorphonuclear leucocytes. The urinalysis was negative. The icteric index was 13 and cephalin flocculation test was 4 + in 24 hours. There was a moderately positive prompt biphasic van den Bergh reaction. Blood cultures taken then and subsequently were reported as negative. Chest roentgenograms were essentially normal.

A diagnosis of rheumatic fever was made and treatment with antipyretics was started. Sulfadiazine therapy was started on March 31, 1944, the 4th day after admission, 1 gram being given every 4 hours, without noticeable clinical improvement. On March



July 7, 1944. July 20, 1944. August 18, 1944. Sept. 3, 1944. September 30, 1944.

Fig. 18. G. C. Case 29.

31, 1944, the roentgenologist described periosteal reaction about the upper two-thirds of the shaft of the humerus with some demineralization of the underlying bone. Repeated x-ray examinations showed gradual increase in these changes which were quite extensive on the 13th hospital day (Fig. 10). Pus was aspirated from a soft tissue abscess over the upper lateral aspect of the arm and the hemolytic streptococcus was cultured from it. At this time we were asked to see the patient, and it was elected to treat the osteomyelitic process with penicillin; 10,000 units were given every 3 hours, intramuscularly (Fig. 9). The soft tissue abscess was again aspirated and 15,000 units of penicillin in 3 cubic centimeters of saline solution was instilled into the abscess cavity. Within 72 hours after the penicillin was started, the temperature fell to 99.2 degrees F. and thereafter this elevation was never exceeded. The subperiosteal abscess was aspirated on two occasions, and penicillin was injected. No organism was cultured from the aspirated material after 8 days of penicillin therapy. The dose was then reduced to 5000 units every 3 hours after the 11th day of penicillin treatment and 2 days later it was discontinued.

He was discharged to the Children's Convalescent Home on his 47th hospital day and under supervision an early return to normal activity was possible. Roentgenograms taken on June 22, 1944, showed marked healing with extensive recalcification. After a stay of 3 months at the institution he returned home entirely without symptoms.

CASE 18. W.S., a 2 month old white male infant, was admitted to the Children's Hospital on March 5, 1944, with a 5 day history of fever, irritability, and tender swelling about the left hip and thigh.

Examination showed an irritable but not acutely ill infant with an area of diffuse swelling over the lateral portion of the left thigh and hip with induration and tenderness. The white blood count was 14,000 cells with 67 per cent polymorphonuclear leucocytes. Urinalysis was negative. Roentgenograms showed definite mottling and decalcification of the upper third of the femur.

The patient was treated conservatively and 4 days after admission the area of swelling had become fluctuant and the temperature rose to 104 degrees F. An incision was made releasing about 50 cubic centimeters of pus. The pneumococcus type III was cultured from the blood stream and pus. Penicillin therapy was started after incision and drainage giving 10,000 units every 3 hours for 3¼ days and 5000 units for 3½ days thereafter at the same interval. The temperature fell precipitously and the general condition rapidly improved (Fig. 11). The wound became clean and the purulent drainage decreased remarkably. He was placed in Buck's extension from March 25, 1944 to May 15, 1944. A left hip spica was applied on May 15, 1944 and changed on June 15, 1944. Serial roentgenograms (Fig. 12) showed progressive destruction of the upper end of the femur during the month following admission. Six weeks later definite healing was evident and was associated with normal growth and calcification of the adjacent epiphysis. The process of healing and growth have continued. When the cast was removed on September 13, 1944, the old incision was completely healed and the infant moved the leg very well. Roentgenograms on September 9, 1944 and October 26, 1944, showed complete healing of the osteomyelitic process.

Fig. 19. R. P. Case 27. Diagnosis: Acute hematogenous osteomyelitis of left humerus. The appearance of the patient at the start of penicillin therapy and 2 weeks later.

CASE 3. J. C., a 13 month old white male infant, was admitted to Children's Hospital on October 23, 1943, with a 3 day history of fever, associated with redness, swelling, and marked pain of the entire left lower leg. He had been given sulfathiazole without obvious clinical improvement.

At the time of admission, marked edema, redness, tenderness of the external malleolus, the shaft of the fibula and the lower end of the tibia were noted. The temperature was 102 degrees F. and the white blood count was 32,000 cells per cubic millimeter. Urinalysis was essentially negative except for the presence of acetone. Blood cultures were negative.

He was treated conservatively by immobilization of the extremity and administration of penicillin using 15,000 units and later 10,000 units every 3 hours intravenously and intramuscularly (Fig. 13). No surgical intervention was done.

Eight days after the onset of symptoms the cast was bivalved and a small subperiosteal abscess was aspirated yielding 12 cubic centimeters of thick gray pus containing staphylococci. The cast was reapplied and the patient continued to receive penicillin and general supportive therapy. On the 5th day after the start of penicillin therapy, the temperature began to fall reaching normal 6 days later. The patient was discharged to his home with no external signs of active inflammation present in the leg. No draining sinuses or residual edema were apparent. Progress x-ray films taken at intervals during the past year are illustrated in Figure 14. During this period the child has moved to another state and contact has been maintained through his orthopedic surgeon. Shortly after moving, he developed two small draining sinuses in the lower part of the affected leg and the roentgenograms showed that a sequestrum had formed in the fibula. During a subsequent change in plaster casts the sequestrum was found to be partially extruded from one of the sinus tracts and it was removed. There has been no disturbance of growth of this leg, no deformity, and no impairments of function of adjacent joints. In October, 1944, the child was reported to be running about normally without complaints or signs of infection.

CASE 22. R. J., a 3 year old negro boy, was admitted to the Cincinnati General Hospital on June 14, 1944. His chief complaint was swelling throughout the right forearm. Two days earlier he had cut his right palm and at that time it was also noted that he had one furuncle on his scalp. Two months before he had been treated in the same hospital for an upper respiratory tract infection and active rickets.

He appeared acutely ill and his temperature was 104.6 degrees F. There was a healing laceration of the left thenar eminence. Extending from the left wrist to the shoulder was a warm, exquisitely tender swelling, greatest throughout the forearm.

The white blood count was 21,000 cells per cubic millimeter and the urinalysis showed the presence of acetone. Blood culture was reported as negative on admission and repeated subsequent examinations. Roentgenograms on his 5th hospital day showed small areas of demineralization and periosteal reaction about the distal end of the radius.

Sulfadiazine was started the day of admission, 7½ grains being given every 4 hours. Massive wet dressings were applied to the arm. After 20 days on sulfadiazine therapy he continued to have daily elevations of temperature to approximately 100 degrees F. and the appearance of the arm did not change appreciably. On roentgen examination the changes in the radius progressed and the distal end of the ulna also showed involvement.

On the 23d hospital day, we were asked to see the patient and penicillin therapy was started giving 10,000 units intramuscularly every 3 hours (Fig. 15). Sulfadiazine was discontinued and the arm was immobilized in a long arm cast. After 5 days the dose was reduced to 5000 units every 3 hours. The course was one of slow improvement. On July 20, 1944, aspiration of the forearm yielded a few cubic centimeters of fluid from which hemolytic Staphylococcus aureus, Staphylococcus albus, and a streptococcus were cultured after 14 days of penicillin therapy. He was discharged on his 56th hospital day, greatly improved. When seen in clinic on August 26, 1944, there was still some swelling of the forearm with a palpable irregularity along the surface of the radius. Progress roentgenograms are illustrated in Figure 16.

CASE 29. G. C., a 2 year old white boy, was admitted on July 6, 1944, to the Children's Hospital, complaining of pain and swelling of the left foot and lower leg of 3 days' duration. Wet dressings had been applied and an unknown type of sulfonamide administered the day before admission. During the preceding 2 weeks he had an acute upper respiratory

infection and 10 weeks before he had had epidemic meningitis from which he had made a complete recovery.

Examination showed an acutely ill white boy whose temperature was 104.2 degrees F. There was a profuse nasal discharge. The left foot was red, hot, tender, and swollen to a level above the ankle. A large vesicle containing blood stained fluid was present over the area of greatest swelling.

The white blood count was 15,250 cells with 86 per cent polymorphonuclear leucocytes and the red blood count was 3,960,000. Urinalysis showed the presence of albumin and an occasional red blood cell. All blood cultures taken were negative. Roentgenograms showed swelling in the soft tissues, but unfortunately they showed only a small portion of the lower leg.

Aspiration of the fluid in the large hemorrhagic vesicle was performed and examination of a stained smear of this material showed the presence of numerous small chained gram positive cocci. These were interpreted as streptococci and tentative diagnosis of hemolytic streptococcic gangrene was made.

Sulfadiazine, 5 grains, and an equal amount of bicarbonate of soda were given every 4 hours. Penicillin was started on the 2d hospital day, 10,000 units being given intramuscularly every 3 hours (Fig. 17).

The patient's condition became rapidly worse during the ensuing 24 hours, and it became evident that he would die before an additional 24 hours. At this time it was learned that the culture of the vesicle fluid showed the Gram positive coccus to be the hemolytic Staphylococcus aureus. Immediate operative intervention was decided upon. On the way to, and in, the operating room the child had two convulsions. Under drop ether anesthesia two long incisions were rapidly made through the skin and subcutaneous tissues of the lateral and medial aspects of the leg and foot. A necrotizing purulent infection was found in the subcutaneous tissues over the entire leg and dorsum of the foot. On the lower lateral aspect of the leg, an area of slough with perforation was found in the fascia. The wound was loosely packed with gauze incorporating four Dakin's tubes and the patient was returned to his room in very poor condition. He received continuous oxygen therapy, intravenous injection of 5 per cent glucose in saline solution and several transfusions of 250 cubic centimeters of fresh whole blood. Penicillin therapy was continued giving 15,000 units every 3 hours for the next 12 days and smaller doses at the same interval for an additional 13 days.

There was striking improvement in his general condition which became evident within the first 24 hours and continued during the following 7 days. The sloughing tissue in the wound became replaced by red healthy granulation tissue, and the wound gradually healed spontaneously with the exception of a small area 2 centimeters in diameter over the lower lateral aspect of the leg.

Roentgenograms 2 weeks later showed destruction and periosteal reaction at the distal ends of the tibia and fibula and involvement of the tibioastragalar joint.

A long leg cast was applied on the 21st day after operation and he was discharged on the 47th day. He was afebrile at this time and his general condition was very good. A small sinus tract was present and this could be traced down to the tibioastragalar joint. In October, 1944, the patient began active weight bearing after removal of the cast. On November 23, 1944, the wound had completely healed, and the patient was without complaint. Progress roentgenograms illustrate the healing which has occurred in the tibia and fibula (Fig. 18).

CASE 6. W. E., a 10 year old white boy, was admitted to the Children's Hospital *in extremis* complaining of severe pain and swelling in the right leg, fever, and shortness of breath. On April 26, 1944, a diagnosis of varicella had been made and 3 days later pain developed in the right knee associated with high fever and local swelling. On April 30, 1944, he had been admitted to a private hospital where sulfadiazine therapy was started. When his general condition became progressively worse and the swelling in the leg increased, he was transferred to this hospital. On admission the patient was found to be a dehydrated, pallid, prostrated, cyanotic, and dyspneic white boy in moribund condition. The oral temperature was 104 degrees F. Râles were audible in both lung fields. The right lower leg was edematous, reddened, and exquisitely tender and several large areas of fluctuation were present in the involved area.

The white blood count was 37,850 cells per cubic millimeter and urinalysis showed only a faint trace of albumin. The blood culture was reported positive with "too many colonies of hemolytic Staphylococcus aureus to count."

This patient's condition was so desperate that it was obvious he could not withstand anesthesia or incision and drainage of the soft tissue abscesses. Conservative therapy was started consisting of the continuous administration of oxygen, injections of 5 per cent glucose and saline solutions by continuous drip, and transfusions of 200 cubic centimeters of fresh whole blood. A posterior molded plaster splint was applied to the leg for immobilization. Penicillin therapy was started immediately, 15,000 units being given intravenously every half hour for 4 doses and every 3 hours thereafter. He failed to respond to this management and died 17 hours after admission. Permission for autopsy could not be obtained.

RESULTS

It is difficult to assess the value of a chemotherapeutic agent in a disease with both generalized and localized manifestations of infection and to determine accurately the result obtained in each case. Penicillin therapy in some instances of severe advanced hematogenous osteomyelitis with bacteriemia sterilized the blood stream, saved the patient's life, and

arrested the local infection, yet the infection had already produced extensive bone necrosis. The general result obtained in such cases might be considered excellent or good, but the severe local destruction of bone produced by the infection, principally before the start of treatment with penicillin, does not wholly justify this.

The mortality rate in this series was unquestionably lessened. Even though the group contained 3 cases of extensive acute osteomyelitis of the skull and 20 cases complicated by proved bacteriemia or septicemia, only 1 death occurred. A severe and neglected case of acute hematogenous osteomyelitis of the tibia with staphylococcal bacteriemia and pneumonia was admitted to the hospital 14 days after the onset and died 17 hours later.

The results obtained in the cases of acute hematogenous osteomyelitis of the major long bones fell into four groups and varied with duration of disease, the onset and adequacy of penicillin therapy, and the severity of the infection.

Group I. If the correct diagnosis was made early, within the first 3 or 4 days, and adequate treatment was started immediately, the results were truly excellent (examples: Cases 17, 24). After a period of 36 to 72 hours, the fever, rapid pulse, bacteriemia, and other general signs of the severe infection began to disappear. At the end of a week the temperature was usually normal and the patient looked and felt quite well. The local signs of infection, such as tenderness, edema, and redness, also began to recede after a similar latent period. In this group immobilization by plaster cast seemed to be of comparatively little importance, and there was an early return of function. In fact, it was practically impossible to keep some children off the involved extremities as early as 2 weeks after the start of treatment. Usually in this group, surgical intervention was not necessary and abscess formation did not become evident.

The bone changes as depicted on the roentgenograms were minimal, consisting of localized periosteal reaction or small areas of patchy decalcification of the underlying cortex or both. These findings may be hard to see and are easily overlooked. An additional 3 cases with typical symptoms and signs of acute osteomyelitis were not included in the report since it was impossible to prove the diagnosis in the absence of roentgenographic findings.

Group II. When the diagnosis and treatment with penicillin were moderately delayed, the general and local infections were brought under control rather promptly after a period of 2, 3 or more days during which little or no clinical response was evident (examples: Cases 4, 5, 21). In this group, local soft tissue abscesses occasionally developed, but they were usually small. When small they were successfully treated by aspiration and local injection of a solution of penicillin at intervals of 2 or more days. If the abscesses were large, surgical drainage by incision was done to minimize further tissue destruction by the accumulated necrotizing bacterial toxins (Case 18). When surgical drainage was instituted, the fall in temperature was usually prompt and not delayed for 36 or more hours as in the cases treated without surgical intervention (Fig. 11).

The bony changes developing in these cases were of great interest. Usually no changes were visible on the roentgenograms at the beginning of treatment. After a week or more had elapsed, periosteal reaction and localized patchy demineralization of the underlying bone became evident and progressively increased in extent and degree, becoming most marked 1 to 5 months after the onset of the infection (Figs. 6, 8, 10, 12). This process previously has been interpreted as representative of further extension of a chronic osteomyelitic process. Recalcification of the demineralized areas followed with re-establishment of a more normal appearance of the bone. Sequestration did not occur in this group.

Group III. When the diagnosis and treatment were delayed for 7 to 10 or more days and when the infection was unusually severe, local destruction of bone became very great and soft tissue abscess formation and sequestration occurred in most, but not all, of the cases. The sequestration, however, was of limited extent and apparently in some cases the sequestrum acted like an autogenous bone graft.

The local infection was arrested with more difficulty in this type of case and longer periods of treatment with penicillin were usually required. Small abscesses were treated by aspiration and large ones by incision and drainage. Prolonged immobilization by cast in these cases seemed to be definitely indicated.

The bony changes as revealed by serial roentgenograms at the start of penicillin treatment showed extensive bone destruction which increased on subsequent examinations. Sequestration occurred in some instances. In Case 3 the sequestrum was partially discharged spontaneously and in Case 22 the sequestrum is still undisturbed. Small sequestra have apparently been absorbed spontaneously, and larger ones possibly have acted as autogenous grafts. These bony changes and results to date are depicted in Figures 16 and 18.

Group IV. In certain fulminating infections in which it is apparent that the patient will not live 48 or more hours to permit the maximum effect of penicillin, surgical intervention after adequate preoperative preparation is still necessary as an emergency measure. Penicillin therapy is administered preoperatively and postoperatively in doses of at least 15,000 units every 1 to 3 hours. An example of this type is found in case report 29.

DISCUSSION OF THE VALUE OF PENICILLIN THERAPY

The principal bacterial cause of acute osteomyelitis is the hemolytic Staphylococcus aureus and less frequent etiologic agents are the nonhemolytic staphylococcus, hemolytic streptococcus, nonhemolytic streptococcus and the pneumococcus. Since these bacteria are sensitive to the action of penicillin, it is not surprising that this chemotherapeutic agent has such a profound effect upon the disease. Sterilization of the blood stream and control of the generalized infection reduce the mortality rate and the incidence of metastatic or secondary infective complications. If metastatic complications, such as staphylococcal pneumonia, pleuritis, pericarditis, thrombophlebitis, etc., already exist, penicillin is a powerful chemotherapeutic agent aiding in their control as an adjunct to surgical or conservative treatment as indicated. Thus morbidity is also decreased.

Of particular interest is the control of the localized infection and the resultant roentgenographic changes in the involved bone treated with or without surgery. During the period of penicillin therapy evidence of bone damage was absent or confined to minimal changes such as slight periosteal reaction or small areas of demineralization in the underlying cortex. After the cessation of chemotherapy, the periosteal reaction and mottled appearance of the underlying bone progressively increased, reaching a maximum 1 to 5 months after the onset of the infection, depending upon the severity of infection. In this way the bone always looked worse a month or more after penicillin therapy than during it. This picture has been interpreted as being the result of spontaneous absorption of bone destroyed early in the infection, and not as the result of continued destruction of bone by an extending chronic osteomyelitic process. Following this, recalcification of the involved areas occurred, often very rapidly. Meanwhile normal growth of the metaphyses, calcification of the adjacent epiphyses, and early return of function occurred. These facts suggest that adequate penicillin therapy may sterilize the infected bone converting an area of septic necrosis to one of aseptic necrosis. If this is true, it will necessitate our re-education in the interpretation of roentgen findings in osteomyelitis.

It has long been known that aseptic absorption of dead bone occurs in transplanted bone grafts (1). When bone is transplanted to another location, a considerable part of it dies, but those bone cells which are still bathed in lymph and body fluids continue to live and show marked proliferation in the course of a few days. Revascularization of the necrosed bone is accomplished by new vessels growing into the haversian canals from the surrounding tissues. Proliferating osteoblasts accompany the new vessels, giant cells appear and the dead bone undergoes absorption and conversion into a series of spaces lined by osteoblasts. The formation of new bone is then accomplished by these cells. In this manner the graft becomes partially absorbed and then replaced. We suspect that a similar process occurs in the dead bone in acute osteomyelitis treated adequately with penicillin.

Acute suppuration of adjacent joints subsided rather promptly leaving surprisingly little residual disturbance in the function of the joint.

Sequestration may still occur occasionally in acute osteomyelitis treated with penicillin, but only when the disease is unusually severe, the diagnosis is delayed, or treatment is inadequate. If sequestration does occur, further conservative therapy seems indicated. Extrusion of a sequestrum followed by complete healing of the sinus and an excellent result has occurred in this group. Further observations are required to determine the best methods of handling the sequestrum.

It is important to realize that no obvious clinical improvement may be apparent for a period of 48 to 72 or more hours after the onset of penicillin therapy in the patients treated without surgery. This is a very trying period during which considerable pressure may be brought to bear upon the surgeon by the pediatricians, internists, or other surgical consultants in favor of immediate surgical intervention. Very close observation is required and a decision to operate may become necessary if the infection becomes so severe that the patient will not survive the 48 or more hours necessary for full penicillin effect. In the majority of instances, however, complicating or metastatic infections should be looked for if a sharp fall in temperature and marked clinical improvement do not occur at the end of this latent period. In the cases with large abscess treated by incision and drainage and penicillin, the clinical response in this series was immediate.

Although this is only a preliminary report, there seems to be little doubt that early and adequate penicillin therapy can eliminate the necessity of surgical intervention in cases of acute osteomyelitis. In the past there has usually occurred a considerable degree of secondary contamination of areas of osteomyelitis treated by surgical drainage. Devitalized tissue exposed to the air invites mixed or saprophytic infection particularly by various gram negative bacilli, and it is often difficult to prevent this type of secondary infection. Secondary invaders have frequently been resistant to penicillin or even destructive to penicillin. The elimination of this complication by penicillin therapy without surgery may be a very important factor in the arrest of the local infective process and the spontaneous absorption of devitalized bone.

Throughout the study and particularly at the start, it took great fortitude to refrain from surgical drainage in individual cases as advised and even insisted upon by associated pediatricians, internists, or consulting surgeons. In some instances surgeons unfamiliar with the action of penicillin were unwilling to complete the conservative treatment and performed local surgical drainage when we believed it was unnecessary. Later in the course of the disease when the roentgenological appearance of the bone became so "bad," it again became difficult to withhold surgery in face of reports that extension of the destructive chronic osteomyelitic process had occurred.

Since the local process in the bone is essentially one of diffusing infection characterized by purulent exudation, thrombosis of adjacent blood vessels, and necrosis, the death of bone may become extensive if the infection is unrecognized or unchecked. In penicillin there is now available a chemotherapeutic agent which can check the infection and even permit spontaneous resolution of the osteomyelitic process. It is apparent therefore that early diagnosis and early intensive penicillin therapy are extremely important if the destruction of bone is to be minimized. It must be emphasized that early diagnosis can only be made on clinical grounds and little or no help is to be expected from the roentgenograms for 10 or more days. If there is any doubt as to the presence of an acute osteomyelitis, it is better to start penicillin therapy rather than wait until the diagnosis is proven.

The results obtained in some of these patients treated without immobilization were so good and recalcification was so rapid that the question of the value of immobilization by cast or splint should be studied further when penicillin is used.

SUMMARY

During the past 21 months 34 cases of acute osteomyelitis in which patients were treated with penicillin have been studied and a pre-

liminary report of the results has been presented. If the diagnosis was made early and penicillin treatment instituted promptly without surgical drainage, both the general and local infections were brought under control so thoroughly that a minimal amount of residual bony damage resulted. Moderate delay in diagnosis and treatment increased the extent of bony damage, but the infection was nevertheless quickly arrested without the aid of drainage and without sequestration. If small localized abscesses developed, they were treated very satisfactorily by aspiration followed by injection of a solution of penicillin. If large abscesses developed, prompt drainage by surgical incision was required. Delay in diagnosis and treatment not only increased the degree of bony damage, but favored the development of large abscesses, sequestra, and metastatic visceral infections.

A period of 36 or more hours after onset of penicillin therapy usually occurred before the beginning of definite clinical improvement even in the cases diagnosed early. Occasionally cases of acute osteomyelitis are seen which are so fulminating that they will not survive the 48 or more hours necessary for the full effect of penicillin. Such cases must be recognized early during penicillin therapy and subjected promptly to the surgical procedure indicated.

Penicillin is a powerful and effective chemotherapeutic agent in the treatment of acute osteomyelitis. When administered early and in adequate amounts, it reduces the mortality and morbidity, brings the infection under control, minimizes local destruction of bone and resultant deformities, permits spontaneous removal of necrosed bone and healing, and makes possible early return of normal or nearly normal function.

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THE TREATMENT OF INTRATHORACIC WOUNDS

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DURING the first year of our participation in this war, the treatment of intrathoracic wounds was the subject of much theoretical conjecture since we had only the rather meager experience of World War I upon which to base opinions. In those years which have come between these two wars knowledge of pulmonary physiology and pathology has greatly increased. This knowledge coupled with proper anesthesia has made possible the safe performance of intrathoracic operations. Whereas such procedures were rare and accompanied by a high fatality rate previous to 1917, they now are commonplace and readily accepted surgical procedures. For these reasons it might be expected that thoracic wounds would be better cared for and that in the end, the results would reflect these surgical improvements.

We have now been at war 2½ years during which time we have engaged in several campaigns in a number of theaters. A large number of thoracic wounds have occurred but only recently have large numbers of this type of injury been seen and treated by individual groups. Thus sufficient statistics are now available to be of use in formulating some definite ideas on the proper management of such cases.

In order to understand well the opinions to be presented herein it is necessary to be somewhat familiar with the train of evacuation. In this theater surgery is done in one of three types of hospitals. The most forward of these is the field hospital which as a rule is set up beside the medical clearing station. Here auxiliary surgical teams work, and to these installations go the abdominal wounds, the severe chest wounds, and the traumatic amputations. Further to the rear are the evacuation hospitals which handle only recent casualties, and still further back the general hospitals where surgery of a more definite nature is done.

A system of triage has been set up so that certain types of wounds go to specified general hospitals. Such a system makes possible the evaluation of treatment and takes advantage of surgical specialists whom certain hospitals may have on their staffs.

This study is based on 320 cases of penetrating or perforating thoracic wounds seen during the winter and spring of 1944. The study has been divided into two groups, namely those patients who have had a thoracotomy done in a forward installation for the purpose of débriding the intrathoracic wound, and a second group of patients who have been treated by conservative and supportive measures in the forward area and were evacuated to a rear echelon hospital for whatever surgery of a more formal nature may have seemed needed. The first group contains 127 patients, the second is composed of 193 cases.

By this method of grouping an attempt has been made to evaluate the merits of treatment in both echelons. Furthermore, a study of these statistics should give some idea as to when and where formal procedures should be done to give the highest percentage of good results with the least morbidity and fatality.

Débridement of the chest wall wound and closure of the sucking wound are accepted surgical procedures. The larger question is when should the débridement be carried to the intrathoracic area, and in which of these injuries is it necessary to perform an early thoracotomy. Injuries to the contents of the pleural cavity which have been used as an indication for performing intrathoracic débridement are listed and will be taken up separately to determine whether or not they constitute an indication:

1. Wounds of the lower chest with possible injury to diaphragm and peritoneal contents.
2. Foreign body, either metallic or bone fragments.

3. Wounds of the mediastinum.
4. Hemothorax.
5. Tension pneumothorax.
6. Hematoma of the lung.

WOUNDS OF THE LOWER CHEST WITH INJURY TO THE DIAPHRAGM

There can be little question but that such wounds should be actively débrided and the débridement carried into the pleural space to determine the exact extent of the injury. There were 51 wounds of the diaphragm in this study. Forty-nine of these patients had had a thoracotomy done in a forward installation with repair of the diaphragm. In 2 instances, wounds of the diaphragm were overlooked. They were both on the right, and there were accompanying wounds of the liver. Each of these patients developed a biliary pleural fistula with subsequent infection of a large overlying hemothorax. Bronchial fistulas were also present. Decortication of the lung with closure of the bronchial fistulas was done in each. In one an excellent result with complete expansion of the lung and removal of the tubes in 10 days was accomplished, in the other the bronchial fistula reopened, the lung collapsed, and a chronic empyema must be accepted.

The remaining 49 patients did extremely well when the gravity of these wounds is considered. As may be seen by examining Table I there were 10 wounds of the spleen requiring splenectomy and 4 wounds of the bowel which were closed through the diaphragm. There were 14 instances of liver injury. In 1 patient the left kidney was injured and was removed through the diaphragmatic opening.

TABLE I.—AN ANALYSIS OF 51 THORACOABDOMINAL WOUNDS

Treatment and extent of wound	No. of cases	Percentage	Results of early treatment		
			Results	No. cases	Per cent
Treated by thoracotomy	49	96.0	Good	27	55.1
Untreated (early)	2	4.0	Fair	6	12.3
Wound of spleen *	10	19.6	Poor	16	32.3
Wound of liver	14	27.4	Further surgery done	16	32.3
Wound of bowel†	4	7.8			
Wound of kidney‡	1	1.9			

*Splenectomy done through diaphragm
†Bowel repaired through diaphragm
‡Kidney (left) through diaphragm

The ultimate results can be seen also in Table I. Twenty-seven cases, or 55.1 per cent, could be called good results, the lung had expanded well, leaving a relatively normal appearing chest. Six patients, or 12.3 per cent, had a fair result and in 16, or 32.6 per cent, the outcome was poor. These 16 patients were operated upon for the second time to correct difficulties which arose following the first operation. Thirteen patients in this latter group developed empyemas, 6 who were considered to have an infected organizing hemothorax were treated by decorticating the lung, 7 were treated by rib resection and drainage of the empyema. One nonpurulent organizing hemothorax was decorticated. The remaining 2 patients had lungs which would not re-expand and a secondary thoracotomy with lysis of constricting fibrinous bands was necessary. The empyemas were healed or healing when the patients were evacuated, and it is believed that none will require further surgery.

Those classified as fair results were so called because of a moderate amount of pleural obscuration in the lower chest, but it was felt that they could not be improved by further surgery.

There were no deaths, although 3 patients had severe liver wounds. Each became deeply icteric and 1 had 4 severe hemorrhages from the liver before we were finally able to find the bleeding vessel and ligate it.

The spleen is readily removed through the diaphragm. In fact it is much more easily removed through the transdiaphragmatic approach than through an abdominal incision. It seems that in civil practice this approach may have distinct merit in the removal of the traumatized spleen as it obviates the dangers of a postoperative abdominal hernia and has the advantage of a much more complete exposure of the vessels. Furthermore individuals with a normal chest so operated upon can be out of bed in 4 to 5 days.

Left thoracoabdominal wounds did better than those on the right probably because of the complicating liver wound. A common

cause of trouble in right sided wounds was neglecting to drain below the diaphragm after the repair had been done. If any suggestion could be made in the care of this type of wound it would be that whenever the liver is damaged the subphrenic space must be drained. This drainage we feel would obviate many of the difficulties encountered both above and below the diaphragm.

Early treatment by thoracotomy of the thoracoabdominal wound is imperative. One has only to witness the extensive complications which develop when these wounds are left uncared for to become cognizant of this point. It is extremely gratifying to see from these figures that of 51 such wounds only 2 were overlooked. Exploration is a sound policy whenever the course of the missile has been such that there is a possibility of injury of the diaphragm. Even though exploration may be carried out in the occasional case in which no diaphragmatic injury is present, still this procedure will save many individuals long periods of convalescence, and in some instances their life.

METALLIC OR BONE FRAGMENT FOREIGN BODIES

There has been considerable discussion relative to the removal of intrapulmonary foreign bodies. During the African and Sicilian campaigns and for several months early in the Italian campaign a size limit of 7 millimeters was set as the criterion for removal. Naturally the location of the foreign body was an important factor when removal was considered. As time has progressed the limits of size were increased and at present only foreign bodies which exceed 1.5 centimeters are removed, unless, even though smaller, their location makes their presence a menace to the host.

Some believe that a foreign body in the pleural space may be more hazardous to the host than one within the lung. In this series we have seen only 1 intrapleural metallic foreign body which was associated with an empyema. Apparently the fear is more theoretical than real. There was a tendency early in the campaign to remove metallic fragments from the lung in the forward installations. As time went on such practices were discouraged, for it was evident that no harm resulted from their temporary retention. Although foreign bodies are often surrounded by a hematoma of varying size into which have been carried fragments of clothing and other foreign substances, in no instances have we seen a lung abscess develop, nor do any of the authors have knowledge of such a happening.

In 26 patients in this study metallic foreign bodies were removed in forward hospitals by the performance of a thoracotomy. As nearly as can be told from records, which in a few instances due to the tactical situation were inadequate, the presence of the foreign body was the only indication for thoracotomy. In this group there were 8 poor results, or 30.7 per cent.

In the total series of 320 patients admitted with penetrating or perforating chest wounds to our hospital there were 68 cases in which foreign bodies were present. In 22 the foreign bodies were considered too small to remove, in 2 instances patients having sizeable metallic foreign bodies were too ill from other wounds to consider removal and were sent to the zone of the interior with a foreign body retained. Forty-four patients had retained metallic fragments of a size which justified removal. Thirty-six of these had only a foreign body as an indication for surgery and were for purposes of comparison quite comparable to the group thoracotomized in forward hospitals. In this group the only postoperative complication was 1 empyema, or a poor result percentage of 2.7 per cent. In the remaining 8 cases the presence of the foreign body was not the only indication for thoracotomy. In 7 instances an organizing hemothorax was present and in 1 case the foreign body was complicated by an empyema. The 7 patients were treated by decorticating the lung with a good result in each instance. The 1 patient who had an empyema was treated with a rib resection and drainage, and the foreign body was removed from the pleural cavity. The empyema healed and the soldier returned to limited duty.

It becomes plain from this tabulation of results that the presence of a metallic intrathoracic foreign body is not necessarily an indication for early surgery. It seems that

removal soon after wounding is accompanied by a certain degree of risk. When the poor results which ran to 30.7 per cent following early removal are compared with those of 2.7 per cent attained in cases in which a late and more elective thoracotomy was done, it becomes clear that early removal is unjustified.

Bone fragments are not infrequently driven into the lung when a rib or scapula is comminuted in the process of wounding. Such fragments constituted an indication for early thoracotomy in 11 cases. The results were good in 7 instances and poor in 4. The reasons for classifying these 4 as poor results were as follows: In 1 instance an anterior thoracotomy had been done at the site of the wound exit. The wound of entrance which had fractured the scapula was not débrided. Four days later a subscapular abscess was drained. On admission to our service a lung abscess was present. At operation a long fragment of bone was found extending from the subscapular abscess to the one within the lung. We were of the opinion that the infection had traveled from beneath the scapula along the bone fragment to the lung where it had infected a hematoma. Two patients still had numerous bone fragments within the lung despite a thoracotomy for their removal. These cases were observed for some time and no trouble was seen to come from the presence of the fragments. The fourth case had an empyema with a large bronchial fistula. The lung was decorticated and the fistula closed. The ultimate result was classified as fair, for while the empyema healed there was still a relatively large amount of dysfunction of the affected side.

Five times bone fragments were known to be present in patients who came to us without forward débridement of a formal nature. In 1 patient they were seen on the x-ray film and were left alone as there seemed to be no indication for their removal. In 4 patients they were an incidental finding at operation, and subsequent review of the x-ray films failed to establish their presence. In 2 of these 4 cases a large bronchial fistula with an empyema was present and the bone fragment was found lying in the lung laceration. Whether its presence was the chief factor in establishment of the fistula cannot be said. It is conceivable that when the fragment was set in motion by the wounding agent it could have badly lacerated the lung; however, it is equally true that the impact of the missile alone was sufficient to tear the lung parenchyma.

Certainly the case against early removal of bone fragments is not as strong as in the case of the metallic foreign body. There is some evidence to show that they may cause trouble of a serious nature. The neurosurgeons have considered them more dangerous from the standpoint of subsequent brain abscess formation than the metallic foreign body. However, the comparison is not entirely valid for the reparative properties of lung and brain tissue are entirely different. We feel that there are two reasons for avoiding a forward thoracotomy in these individuals. The first is that bone fragments are often exceedingly hard to find in a badly wounded lung when the hematoma is still present and the second is that early thoracotomy carries a higher percentage of poor results than those performed at a later period. A larger series of cases is needed to establish a policy consistent with good surgical principles.

WOUNDS OF THE MEDIASTINUM, HEART, AND PERICARDIUM

The number of patients with wounds of this nature seen alive is, by reason of their location, relatively small. Seventeen such cases have been seen. Nine had had an early thoracotomy done. Of these 3 had wounds which had lacerated the pericardium. There was 1 stab wound of the heart, with a cardiac tamponade, which was repaired; the patient subsequently developed a purulent pericarditis which was drained and he made an uneventful recovery. In another patient the heart, which had been lacerated by a piece of shell fragment, was sutured and recovery was uneventful. Four times the mediastinum was wounded without injury to any important structures; in 2 patients the missile traversed the mediastinum and came to rest in the opposite lung from which it was subsequently removed. In 3 patients in this group there was electrocardiagraphic evidence of myocardial damage. The results which were obtained in these 9 cases were all good.

Eight patients were admitted to this hospital with foreign bodies in the mediastinum or pericardium. There were 3 instances of pericardial foreign body, in 2 the fragments were removed, in 1 the missile was extremely small and was left in place. Five patients had mediastinal foreign bodies of varying size. One which was extremely small was not touched. The remaining 4 were operated upon. The foreign bodies were found in 3, in 1 the missile was never located. The postoperative course was uneventful in each case.

Early thoracotomy should undoubtedly be done in those cases in which the posterior mediastinum has been wounded because of the possibility of esophageal injury. For practical purposes the esophagus is the only important mediastinal structure the wounding of which, if not followed by early repair, may give serious results.

It would seem relatively safe to leave fragments in the anterior mediastinum for subsequent removal. Pericardial lacerations should be repaired, but it is often difficult to tell just when the pericardium has suffered. Cardiac tamponade, resulting from cardiac laceration, requires immediate surgery.

In wounds of the mediastinum as in those of the diaphragm the wound of entrance and the course of the missile will have much to do with determining whether early surgery should or should not be done. If there is any question as to the possible damage to important structures, early surgery is the only course in keeping with good practice.

HEMOTHORAX

Hemothorax is seen in a large percentage of chest wounds. In civil practice there have been two schools of thought, namely those who did nothing with the blood within the pleural space and those who felt it should be removed by aspiration. From reports of these two methods of treatment the results seemed always good. It is true that patients seen in civil life by the authors and treated by aspiration alone did well, and thoracotomy in such individuals was rarely done. When aspiration was done and the blood was removed, the lung promptly expanded. The presence of residual obscuration of the lung on x-ray examination was rare and recovery was almost invariably rapid and complete. This has not been true in all cases of hemothorax seen here. Often within a few hours after wounding it was impossible to obtain any blood from the pleural space, despite x-ray evidence of fluid. The answer was that the blood had already clotted. Such a situation led to the performance of early thoracotomy to remove the clot and suture the bleeding lung, for it was felt that early removal of the clot would speed recovery. As time went on it was realized that so simple a solution was not the answer to a problem which constantly gathered to itself more complications.

In this study there were 31 early thoracotomies done for hemothorax alone. The blood within the pleural space was not clotted in all instances. From this number of thoracotomies only 10, or 32.2 per cent, could be called good results; of the remainder 3, or 9.8 per cent, were considered fair results; and 18, or 58.0 per cent, were definitely poor.

The 3 cases classified as fair were so called because of moderate pleural obscuration by x-ray examination. There is some question now on reviewing these films as to whether subsequent surgery should not have been done in 1 of these, but our early opinion was that the lesion would clear. This it did moderately well; however, we feel now that in the present state of our knowledge of such things the lung should have been decorticated.

The 18 cases tabulated as poor results were so classified because of the following reasons. Fourteen patients subsequently developed empyemas. Seven of these were treated by decorticating the lung on the involved side, 7 had a rib resection with drainage of the pleural cavity. Most of these who were treated by drainage alone would now be decorticated because they represented infected organizing hemathoraces; however, they were seen early in our experience, they were localized empyemas, and it was felt safer to treat them by simple drainage. Three patients who had an organizing hemothorax were operated upon and the lungs on the involved sides were decorticated. One patient had an organizing hemothorax of a mild degree and because of other wounds, which complicated the situation, no further

surgery was considered wise. His course was afebrile and the need for immediate surgery was not considered urgent.

Eight of the 17 patients operated upon had completely expanded lungs at the time of discharge. Nine still had an empyema tube in the pleural cavity. Two of these 9 had a large bronchial fistula in a small empyema pocket. They will probably need further surgery. The remaining 7 had small empyema pockets which were obliterating.

One hundred and nineteen patients with hemothorax who had had no previous treatment other than débridement of the chest wall wound and aspiration of the pleural cavity were admitted to our service. Seventy-six, or 63.8 per cent, of the group cleared completely or almost so by aspiration alone. Four patients who had a moderate amount of pleural obscuring but not enough to require further surgery were called fair results. Thirty-nine, or 32.9 per cent, failed to clear. In some of these aspiration had never been possible and in others it was possible to obtain fluid early, while later attempts at aspiration gave negative results despite evidence of fluid by x-ray examination. Nineteen of the 39 cases of organizing hemothorax were grossly infected and must be considered empyemas.

The 39 patients who failed to clear by aspiration alone were subjected to further surgery. In 30 instances the lung was decorticated, 10 patients in this group had gross evidence of infection at the time of surgery. The remaining 9 cases were treated by rib resection and drainage of an empyema. Twenty-seven of the 30 patients whose lung on the affected side was decorticated obtained good results; 3 had a poor result. Two of the group will have a chronic empyema and will need further surgery, 1 has an empyema which is slowly expanding and because of the progress made under our observation we feel the lung will completely expand. In 9 instances in which a frank empyema was present and rib resection with drainage was the procedure used, good results with the complete expansion of the lung were obtained in 7. One patient had a large bronchial fistula and will require further surgery. The remaining patient had an empyema which was diminishing rapidly in size when he developed a brain abscess approximately 3 weeks after drainage and died.

The question may arise in the minds of some as to when simple drainage of an empyema is resorted to and when the lung is decorticated. This subject will be discussed more fully in a subsequent communication. To state the problem briefly we have decorticated those who had evidence of an organizing hemothorax which was known to be partially infected but in which liquefaction of the clot was proceeding slowly. We have drained those who had a small localized empyema in which we felt that the lung was expansible and the fibrin peel had been completely liquefied. With the advent of penicillin as an adjunct to surgery and a better knowledge of the surgery involved, decortication is considered a more useful procedure than open drainage in such cases, for it allows the patient to have an expanded lung more quickly, it obviates the wearing of an empyema tube for a long period of time and reduces the incidence of chronic empyema.

To summarize these cases it will be seen that of 119 patients with hemothorax who were not thoracotomized early 110, or 92.4 per cent, had a good result, 4 were classified as fair, 4 as poor, and 1 died. These figures should be compared with the results obtained in the group who had an early thoracotomy for hemothorax, where the percentage of good results was 32.2 per cent, and the poor results ran to 58 per cent. There were 19 empyemas in a group of 119 patients treated conservatively early as compared with 14 empyemas in 31 patients who had an early thoracotomy.

It may be said that these two groups are not entirely comparable and that is granted. However, if the 39 patients who ultimately came to surgery late are compared with the 31 who had early thoracotomy the comparison is still striking, the good result percentage in the first group being 87.1 per cent as compared with 32.2 per cent in the latter. Furthermore, 17 of the latter group subsequently underwent further surgery for either an empyema or an organizing hemothorax.

The argument has been raised that thoracotomy has been done early to stop lung

bleeding. Lung bleeding is a transitory thing as is evidenced by the fact that in only 1 case of 127 upon whom forward thoracotomy was done was a bleeding lung seen. With the collapse of the lung which comes as the hemothorax increases the bleeding stops. Intercostal vessels have been seen to bleed more often than the lung but these can be controlled in the original débridement by removal of a small segment of rib and ligation of the vessel. The pleural cavity need not be violated.

There can be no question but that hemothorax as we see it here presents an entirely different picture from that seen in civil practice. The method of wounding is of course different. In civilian experience the wounding agent is as a rule a pistol or rifle bullet of small caliber or a sharp weapon of small size. The majority of these wounds discussed here were produced by shell fragments which have rough edges, which whirl in their passage and do great trauma to the tissues through which they pass. It is not uncommon in these wounds to see the tissues contused and bleeding for some distance from the path of the missile. Severe hemothorax has been seen in instances in which the wounding missile never entered the pleural space. The dissimilarity in the wounding agents may account for the difference in the behavior of hemothorax here and at home. While there still may exist doubts in the minds of some as to the cause, there is no question that a marked difference exists. From our figures it seems evident that approximately 30 per cent of hemothoraces treated conservatively will need subsequent surgery. However, there is little question but that such a method of treatment gives infinitely better results than can be obtained by early thoracotomy.

TENSION PNEUMOTHORAX

Strangely enough pneumothorax of a tension type has not been a serious complication in these wounds. Tension pneumothorax can arise in two ways, from an external wound which sucks air in but will not release it or from a lung wound which pumps air into a pleural cavity from which there is no avenue of escape. In talking to recipients of these wounds it is clear that the average soldier, as soon as he hears the wound suck applies pressure with his hand or lies on the wound until the aid man, who promptly applies a pressure dressing, arrives. These two things have tended greatly to obviate the dangers of the sucking wound. Tension pneumothorax from the wounded lung has not been common. When seen it has been treated early by aspiration. If this has failed to keep up with the air escape a catheter is placed in the chest at the field hospital. In only 2 instances was an early thoracotomy done to close what was apparently a large lung laceration, with tension pneumothorax. In both instances catheter water seal drainage had not controlled the pneumothorax. Such a procedure seems entirely justified in a wound in which catheter drainage after a reasonable length of time has not brought about lung expansion.

Subcutaneous emphysema, which has been the nightmare of older surgeons engaged in treating the wounded, has been seen only rarely in a degree to which it presented a problem. There is often a small amount of air in the tissues about the wound but in only 1 case in this series did an emphysema of a serious nature develop. Why have these two conditions, namely tension pneumothorax and extreme degrees of subcutaneous emphysema, which we worried greatly about during those days when we were preparing for combat turned out to be of such minor importance? It seems that the establishment of the hemothorax with a small amount of pneumothorax quickly collapses the lung with the result that both bleeding and air escape cease. These lungs collapse quickly and uniformly because there are no adhesions to hold them to the chest wall. By such a mechanism the wounds are quickly sealed. It must be remembered that we are dealing with young individuals who have been carefully screened by history and by physical and by x-ray examination, to rule out pulmonary disease. This explanation is also not entirely theoretical for in over 200 thoracotomies which are included in this series in only 2 cases were adhesions present which bound the lung to the chest wall. Furthermore x-ray films taken soon after wounding show that adhesions are only rarely present. It may therefore be said that x-ray

TABLE II.—TOTAL RESULTS, FORWARD THORACOTOMY

	Good		Fair		Poor		Total No.	Further surgery No.
	No.	Per cent	No.	Per cent	No.	Per cent		
Wound, diaphragm	27	55.1	6	12.3	16	32.6	49	16
Foreign bodies	17	65.7	1	3.6	8	30.7	26	8
Hemothorax	10	32.2	3	9.8	18	58.	31	18
Bone fragments	7	63.6	1	9 1	3	27.3	11	2
Tension pneumothorax	1	50.	0	0	1	50.	2	1
Wound, mediastinum	6	75.	0	0	2	25.	8	3
Total	68	54.3	11	79.	48	37.8	127	48

screening on induction has played a part unthought of at the time of its inception.

HEMATOMA OF THE LUNG

Hematomas of the lung may result from wounds of the lung or from the contusion which occurs when the chest wall is wounded without pleural penetration. We have seen 1 hematoma which involved over three-fourths of the upper lobe result from a wound which transected the spinal cord and furrowed through the shoulder girdle on its way out. There was no pleural penetration.

Hematoma has presented no problem. As a rule they clear almost completely in from 1 to 4 weeks depending on their size. On 3 occasions we have seen the hematoma break down and leave a round cyst-like cavity which upon further observations closed, leaving a normal appearing lung. One of these patients had a fluid level and coughed up old blood for some days, the temperature remained normal and recovery was complete. Purely on the basis of theory one might expect abscesses to develop in these ideal sites. We have seen but 1 case in which an abscess developed and this, we feel, was infected from a bone fragment which communicated the hematoma with an extrapleural abscess.

Large metallic foreign bodies have been seen lying in the center of hematomas and have caused no trouble. We have come to feel that it is best to let the hematoma resolve before removing the foreign body, the reason for this belief being that it would be necessary to evacuate the hematoma to remove the missile. Such a procedure leaves a large defect in the lung which must be closed by wedge resection. Early in our experience such problems were encountered. If the hematoma is allowed to resolve, the foreign body can be removed by simply incising the lung. It is then removed through normal tissue which can be closed with a few fine silk sutures. It is remarkable to see how normal these lungs are a few weeks after wounding.

The lung has remarkable ability to heal. We have seen lungs which aside from an organizing hemothorax were otherwise normal, which only a few weeks previous had been so badly contused that the surgeon had considered lobectomy. It is important to remember that a lung which a few hours after wounding may appear hopelessly damaged will be almost normal in appearance a few weeks later.

DISCUSSION

We wish to make clear that the comparison of the results of forward installations with our own is in no way an attempt to depreciate the work of those who see these injuries early. It is rather an attempt to learn what is best treated early and what is better treated late. The problems met here have not been met before and it is only by such candid analysis of failure and success that we can come to conclusions which will aid our efforts.

In all 127 patients with thoracotomies done early have been compared with 193 treated conservatively early, definitive treatment being left until later. The results of the first series are as follows: 68 cases, or 54.3 per cent, are to be considered good results regardless of the indication for which they were done; 11, or 7.9 per cent, were fair results and 48, or 27.8 per cent, were poor. It was necessary to do opera-

tions of a secondary nature in 48 of the 127 patients mentioned. This figure represents 27.8 per cent of the total. Seventeen empyemas were drained, 21 lungs were decorticated for an organizing hemothorax with or without an associated empyema, 3 foreign bodies were removed, and 1 lung abscess was drained. Five patients had a lung which would not expand and needed a subsequent thoracotomy with lysis of adhesions to aid re-expansion. One large chest wall defect was closed.

These results can be compared with those obtained in 84 thoracotomies done on this service in 29 of which the operative procedure was their second thoracotomy. There were in this group 66 good results or 78.5 per cent, 12, or 14.2 per cent, fair results, and 6, or 7.5 per cent, poor results.

It becomes evident from these figures that early thoracotomy does not give the good results which can be expected from thoracotomy done late even at times for complications which were more serious than the original wound. It has been the experience of those in this theater that early thoracotomy will at best give about 50 per cent good results.

There are certain reasons for this, some of which are avoidable and others not. It seems to us that most of the poor outcomes encountered can be attributed to failure of the lung to expand on the side operated upon. One as a rule has little trouble with subsequent empyema following surgery if the lung rapidly expands to fill the pleural space.

These thoracotomies were done in many instances on badly wounded lungs. In such cases a hematoma may be present and the lung may show other pathologic states such as edema and patchy atelectasis. Such states prevent proper expansion of the lung. Numerous fine moist râles and rhonchi are a common finding in these individuals. This condition has been called wet lung of trauma. Great care has been taken by our forward surgeons to perform bronchoscopies after all thoracotomies, but bronchoscopy, while a definite help, clears only the large airway obstruction. Therefore, a situation arises for which little can be done except to avoid thoracotomy in any case in which it is not a necessity to preserve life and lessen later complications.

Hemothorax develops early and is often clotted at the time surgery is done. There is already a fine film of fibrin deposited on the lung surface which definitely impedes expansion. When this lacework of fibrin has been deposited it is almost impossible to remove it at this early stage. Thus the lung expands poorly because of the fact that it is wet and as it dries it is held in the unexpanded state by a coat of fibrin which gradually becomes heavier.

There is still another factor that may have some bearing on the behavior of some of these patients. The large majority of those cases were seen during the winter of 1944. It was cold along the Rapido and before Cassino, rain fell frequently in the low lands, and in the mountains which flanked the valleys snow fell. There was little shelter, many of the troops had respiratory infections. Evacuation was difficult because of the terrain, and wounded men often lay for long periods before they could be removed. This combination certainly increased the hazards of a wet lung or laid the groundwork for it.

There have long been two schools of thought as to the advantage of draining the pleural cavity after surgery. We were impressed with the frequency with which the thoracotomies were closed without drainage. To us it had always seemed that water seal drainage for a period of 48 to 72 hours after intrathoracic surgery had distinct advantages. In this group no drainage was used in 37 cases. A comparison of the good and poor results from the drainage standpoint is enlightening. In 90 patients who had thoracotomy and were drained the results were good in 60 per cent of the cases. Whereas in 37 cases in which drainage was not done the results were good in only 35.1 per cent. Such results lend credence to the belief of a large number of thoracic surgeons that drainage of the pleural cavity after intrathoracic surgical procedures has virtue. This fact, it seems, is doubly true in these types of injury in which rapid lung expansion is a prime factor in the avoidance of empyema.

There were 54 patients in the entire series of 320 who developed an empyema, or an incidence of 16.8 per cent. Empyema occurred in 34 of the 127 patients who had early

thoracotomy, or 26.3 per cent. There were 20 cases of empyema in 193 patients treated conservatively early. The incidence of empyema in these patients who had an early thoracotomy done is lower than has been the experience of some other groups in this area. The reason for this we do not know, unless it be that when an organizing hemothorax was present we adopted a policy of early decortication of the lung. Early in the Tunisian and Sicilian campaigns it was not uncommon to see individuals who had an organizing hemothorax develop empyema in from 6 to 8 weeks after wounding. It is our experience that a very high percentage of organizing hemothoraces are infected, as demonstrated by positive cultures of the peel, even though the clinical course would belie it. Thus early removal of the peel may have obviated the development of an empyema in a number of our cases. We have adopted a policy of decorticating these lungs from 3 to 4 weeks after wounding. Earlier attempts find the peel too friable to be consistent with good removal.

There were 6 patients in the entire series who we believe will need further surgery to restore them to normal beings. Four of these have unclosed bronchial fistulas, 2 have a moderately large chronic empyema. Empyemas, which have developed on the basis of an infected hemothorax, in our experience and in that of others, have often become chronic. Decortication of the lung in these cases has been of great aid in preventing the occurrence of chronic empyema. Sixty-one of the total series returned to full duty, 104 returned to limited service, which included all types of duty except combat. Sixty-one were sent to the zone of the interior because of the severity of their chest wounds. Ninety were sent to the zone of the interior because of other wounds, their chest wounds were healed and would not have hindered their return to full or limited service. Thus, of 320 penetrating or perforating chest wounds 255 were able, as far as this type of wound was concerned, to return to full or limited duty.

There were 4 deaths in the entire group, or an incidence of 1.2 per cent. The causes of these deaths are as follows: One patient who had had an early thoracotomy for a hemothorax and who had an excellent result developed a pulmonary embolus 20 days after operation. One patient who developed an empyema following a hemothorax and who was treated by open drainage died approximately 3 weeks later of a brain abscess. The third patient was admitted *in extremis* 3 days after wounding with a hemopneumothorax and a transverse myelitis at the 4th dorsal. A catheter was placed in the left pleural cavity. He failed to improve and died within 10 hours of admission. The fourth patient was admitted approximately 10 days after a severe chest and abdominal wound. An abscess was present in the left upper lobe and a peritonitis with a paralytic ileus was present. Decompression with a Miller-Abbott tube was done. Three days later the abdominal wound disrupted. This wound was repaired but death occurred 24 hours later.

When the number of complications which arose in this series and the severity of wounds are considered, a group of 6 patients is not too great a number to return home for further surgery.

We feel that a number of factors have made such results possible. In the last war one large factor in the invaliding of large numbers of soldiers was the presence of a chronic empyema. Decortication of the lung, while an old and discarded procedure, has in many instances in this series spelled the difference between a relatively normal chest and a chronic empyema. In fact, in the group of empyemas cited here several were 3 months old and chronic when we first saw them. Their lungs were decorticated and they are now well.

Early intrathoracic débridement in the thoracoabdominal wound has without doubt saved many lives. It restored the integrity of the respective body cavities which had been destroyed by wounding. Many of the patients mentioned would have surely died had it not been for the early and adequate care which they received.

It becomes clear that hospitals are very necessary near the lines. It is also clear that the personnel of these installations must be well trained surgical specialists in order to be able to cope with the heavy and intricate problems which face them. It is distinctly a

credit to our Army that the man power and materials have been made available in these places. If lives are to be saved it is necessary to have forward installations with men and equipment capable of restoring deranged physiology. It is likewise necessary to have farther back centers containing suitably trained surgeons to care for the pathologic conditions produced by early injuries. Such advantages we have had and to us the results here tabulated reflect it.

Chemotherapy has been used when it was thought to have virtue. In the patients operated upon by us, the sulfonamides have been used but rarely. The bacteria encountered were known to be resistant to this type of therapy and therefore no good reason could be seen for their use. Penicillin was available in large amounts only during the last 2 months of the time in which this work was done. It is our present feeling that it has been of distinct aid but because of lack of an adequate comparative series our ideas are still not fully crystallized. Undoubtedly, the greatest factors have been the adequate replacement of blood loss and careful surgery. Before extensive restorative procedures are undertaken, the blood picture should be as near normal as is possible. This may mean waiting a few days. At times, as much as 3,000 to 4,000 cubic centimeters of blood are given. We have found that the delay in these cases is well worth while.

Proper anesthesics administered by well trained physicians and nurses have been of great value. Intratracheal, nitrous oxide gas, oxygen, and ether anesthesia has been routinely used. It is evident to us that much of the work could not have been attempted had not excellent anesthesia methods been available.

These results we believe reveal that lung wounds properly treated can and do give encouraging results. They also indicate that definite surgery should be done whenever possible in the theater because of the high percentage of patients capable of returning to some form of duty.

SUMMARY AND CONCLUSIONS

1. Three hundred and twenty cases of penetrating or perforating wounds have been observed and the results of treatment recorded.

2. The results of early definitive surgery have been compared with delayed definitive surgery.

3. Fifty-four empyemas developed, or an incidence of 16.8 per cent.

4. Sixty-one patients returned to full duty, 104 to limited duty in this theater, 90 were returned to the United States because of wounds other than the chest wound which was healed and would not have hindered return to full or limited duty, 61 were returned to the United States because of their chest wound, 4 died.

5. Six patients will need further surgery to obliterate a chronic empyema, 4 of which had an accompanying bronchial fistula.

6. Hemothorax is best treated by early aspiration; if clotting occurs and organization takes place, decortication of the lung should be done.

7. Early thoracotomy for clotted hemothorax does not obviate the possibility of a later organizing hemothorax, and the percentage of empyemas is higher than in the conservatively treated group.

8. Intrapulmonary foreign bodies are removed from the lung with a lower percentage of poor results after the acute process of wounding is past, i.e., 2 to 3 weeks after wounding.

9. Early thoracotomy is indicated in wounds of the mediastinum, especially the postmediastinum, in wounds of the diaphragm, and in tension pneumothorax not controlled by catheter drainage.

EXPERIENCE WITH LUMBAR SYMPATHETIC GANGLIONECTOMY FOR WOUNDS OF MAJOR BLOOD VESSELS OF THE LOWER EXTREMITY

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CIVILIAN experience with sympathectomy in the treatment of vascular disease made us anxious to determine whether or not this operation would be of value in the management of acute peripheral vascular trauma due to war wounds. This report is based on observations made in first priority surgical hospitals (platoons of field hospitals) over a period of 11 months. During this time we have treated approximately 500 freshly wounded urgent battle casualties with wounds of all types. Only 4 of these patients had wounds for which we felt lumbar ganglionectomy to be indicated and in these 4 the operation was performed. We have done sympathectomy on 4 additional patients seen in consultation with other surgeons of this group. These 8 cases form the basis of this report. The series is small, but it will be appreciated that the number of patients for whom ganglionectomy may be considered form a very small percentage of the casualties seen in a fairly extensive and representative surgical experience.

We believe that patients presenting peripheral vascular wounds should have ganglionectomy performed for the following reasons:

1. To encourage collateral circulation as far as possible, by promoting a regional vasodilatation in the extremity. Ganglionectomy does this by interruption of the sympathetic vasoconstrictor impulses.

2. To relieve spasm in the arterial tree of the extremity, in the knowledge that severe vasospasm may exist either with or without gross injury to a vessel wall.

3. In the hope that, should amputation eventually become necessary, it might be performed at a lower level, and a healthier stump be obtained in the presence of enhanced collateral circulation.

4. In the hope that, the increased circulation after ganglionectomy might help to lessen the likelihood of anaerobic infection.

Trauma to the great peripheral vessels may be of four types: (1) that in which the vessel is so severely torn that loss of continuity is inevitable; (2) that in which the vessel is so damaged that repair by suture is possible, with re-establishment of continuity; (3) that in which the wound has led to thrombosis of a vessel, with or without actually perforating its wall; (4) that in which the integrity of the vessel wall is not impaired, but in which severe spasm of one or more vessels occurs as the result of trauma to the extremity. It will be understood that the element of spasm may be present in types 1 to 3 as well as in type 4.

We observed that paravertebral block with procaine was frequently used as an adjunct to the treatment of major peripheral vascular wounds. The rationale of this procedure is fundamentally the same as that for operative ganglionectomy: viz., that by abolishing sympathetic vasoconstrictor impulses, maximal vasodilatation of the lower extremity is accomplished, and the collateral circulation is thereby enhanced. It is also a well established fact that procaine block of the lumbar sympathetics is an appropriate means of eliminating vasospasm. We feel that an effective procaine block, repeated at the customary 8 or 12 hour intervals, should suffice in management of wounds of type 4 mentioned, and also in wounds of type 2 in which a satisfactory repair of the vessel has been secured and blood flow distal to the suture line demon-

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credit to our Army that the man power and materials have been made available in these places. If lives are to be saved it is necessary to have forward installations with men and equipment capable of restoring deranged physiology. It is likewise necessary to have farther back centers containing suitably trained surgeons to care for the pathologic conditions produced by early injuries. Such advantages we have had and to us the results here tabulated reflect it.

Chemotherapy has been used when it was thought to have virtue. In the patients operated upon by us, the sulfonamides have been used but rarely. The bacteria encountered were known to be resistant to this type of therapy and therefore no good reason could be seen for their use. Penicillin was available in large amounts only during the last 2 months of the time in which this work was done. It is our present feeling that it has been of distinct aid but because of lack of an adequate comparative series our ideas are still not fully crystallized. Undoubtedly, the greatest factors have been the adequate replacement of blood loss and careful surgery. Before extensive restorative procedures are undertaken, the blood picture should be as near normal as is possible. This may mean waiting a few days. At times, as much as 3,000 to 4,000 cubic centimeters of blood are given. We have found that the delay in these cases is well worth while.

Proper anesthesics administered by well trained physicians and nurses have been of great value. Intratracheal, nitrous oxide gas, oxygen, and ether anesthesia has been routinely used. It is evident to us that much of the work could not have been attempted had not excellent anesthesia methods been available.

These results we believe reveal that lung wounds properly treated can and do give encouraging results. They also indicate that definite surgery should be done whenever possible in the theater because of the high percentage of patients capable of returning to some form of duty.

SUMMARY AND CONCLUSIONS

1. Three hundred and twenty cases of penetrating or perforating wounds have been observed and the results of treatment recorded.

2. The results of early definitive surgery have been compared with delayed definitive surgery.

3. Fifty-four empyemas developed, or an incidence of 16.8 per cent.

4. Sixty-one patients returned to full duty, 104 to limited duty in this theater, 90 were returned to the United States because of wounds other than the chest wound which was healed and would not have hindered return to full or limited duty, 61 were returned to the United States because of their chest wound, 4 died.

5. Six patients will need further surgery to obliterate a chronic empyema, 4 of which had an accompanying bronchial fistula.

6. Hemothorax is best treated by early aspiration; if clotting occurs and organization takes place, decortication of the lung should be done.

7. Early thoracotomy for clotted hemothorax does not obviate the possibility of a later organizing hemothorax, and the percentage of empyemas is higher than in the conservatively treated group.

8. Intrapulmonary foreign bodies are removed from the lung with a lower percentage of poor results after the acute process of wounding is past, i.e., 2 to 3 weeks after wounding.

9. Early thoracotomy is indicated in wounds of the mediastinum, especially the postmediastinum, in wounds of the diaphragm, and in tension pneumothorax not controlled by catheter drainage.

EXPERIENCE WITH LUMBAR SYMPATHETIC GANGLIONECTOMY FOR WOUNDS OF MAJOR BLOOD VESSELS OF THE LOWER EXTREMITY

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strated at the time of operation. We have had no experience with wounds of type 3.

It is in wounds of type 1, however, in which there is injury to the vessel which necessitates permanent occlusion (ligation) that we feel ganglionectomy may prove most useful. Here we are dealing with the loss of all or a part of the major blood supply to a limb, in addition at times to an associated vasospasm. The early establishment of adequate collateral circulation is imperative if the limb is to be saved. We feel that if any effort is to be made to save such an extremity, all possible means should be employed and there should be no temporizing or half-measures.

Ganglionectomy was selected as the procedure of choice in these cases for the following reasons.

1. The beneficial effect of paravertebral block with procaine is transitory, and the injection must be frequently repeated.

2. Technical difficulty in obtaining adequate block with procaine has been encountered, with failure to obtain the desired effects in some cases. The same may be said for alcohol injection.

3. We believe that ganglionectomy serves as a prophylactic measure against thrombosis. The débrided missile wound must be left open. The vessels can at best be protected only by lightly suturing the fascia over them; further closure is contrary to one of the cardinal rules of war surgery. Vessels which lie near the site of the wound but which have been spared and upon which the survival of the extremity may depend are susceptible to thrombosis. This danger is probably greater in the presence of an open wound than it would be if primary suture were possible; should sepsis occur, the threat is increased. By reason of its increased volume of flow, a sympathectomized vessel is less likely to become the site of thrombus than one not so denervated. Should a surviving major vessel become occluded, collateral circulation in the sympathectomized extremity will be more adequate than if operation were not done.

4. If paravertebral block is employed, repeated injections may be necessary in patients who are desperately ill with associated thoracic, abdominal, or head injuries. Movement of these patients to and from the operating tent is likely to precipitate shock and should be avoided if it is possible, particularly in the early postoperative period. The presence of a plaster spica for concurrent fracture in some cases makes paravertebral block impossible. Furthermore, the procedure of paravertebral block is technically most difficult to perform with the patient on a low cot in a crowded ward tent.

5. Even though the difficulties enumerated in paragraph 4 are not always present, the surgical removal of the appropriate lumbar sympathetic ganglia is advocated because it is the only certain means of obtaining the desired effects.

Our experience has convinced us that ganglionectomy is a feasible procedure, even in the severely wounded. We have had no mortality and no morbidity attributable to the performance of lumbar sympathetic ganglionectomy. The opinion has at times been expressed that the severely wounded battle casualty is a poor risk for extensive surgery, and that in face of prolonged procedures these men do not survive. Our observation has been to the contrary, both in wounds of the extremities and in other types. We feel that disaster is more likely to occur from incomplete surgery than from more prolonged but thorough procedures. The severely wounded soldier, given adequate and continuing shock treatment and expert anesthesia, will survive procedures of considerable magnitude and duration. We are strongly opposed to the school of thought which urges the surgeon to "get the patient off the table before he dies." This fear of a death on the table may lead to hurried and inadequate operations. The surgery must be complete, otherwise the patient may be lost from complications which might have been prevented.

Eight lumbar sympathetic ganglionectomies for acute vascular injuries of the lower extremities are reported, the total number that we have performed up to the time of this writing. In 6 cases, amputation subsequently became necessary. The other 2 patients achieved sound, normal legs. On the basis of these results, one can neither praise nor condemn the procedure as used for this type of

injury. We intend to continue its use in the effort to determine definitely its place in the management of acute vascular wounds. A larger series of cases and knowledge of the experience of others may yet prove its usefulness.

CASE REPORTS

CASE 1. Civilian, aged 12 years. Wounded by hand grenade at 3:30 p. m. December 9, 1943. He was brought to the field hospital 2 hours after injury. A bulky pressure dressing had been applied to the right groin, partially controlling hemorrhage. Examination showed superficial wounds of the abdominal wall and right lower leg, and a 3 centimeter penetrating wound of the right groin from which there was active bleeding. The patient was in marked erethismic shock, pale, and with unobtainable pulse and blood pressure. During administration of blood and plasma in the shock tent, hemorrhage from the groin became so profuse that the patient was anesthetized by open drop ether, and the vessels were clamped. The calf was not tense. At no time was any pulsation felt in the arteries of the foot.

After initial shock treatment, the anesthetized patient was taken into the operating tent. Operation was commenced at 7:30 p.m. The femoral artery was found to be completely severed about 1 inch below the origin of the profunda. The latter artery was intact and pulsating. The femoral artery was ligated with silk. The femoral vein was completely severed at the level of the origin of the profunda branch, and its ends were ligated with silk. The foreign body, which lay in the region of the hip joint, was not found. The other wounds were débrided. Right lumbar paravertebral block was done, distributing 12 cubic centimeters of 1 per cent procaine in the region of the 2d, 3d, and 4th lumbar ganglia. The foot was warm, pink, and dry at the end of the operation. A bulky cotton dressing was applied to the entire leg.

The following morning the leg and foot still appeared viable. At 10:30 a.m., right lumbar sympathectomy was done through the approach advocated by Smithwick, and the 2d and 3d ganglia with the intervening chain were removed. Following operation and until evacuation 12 days later, the right foot was dry and warmer than the left.

This was our first case. The child was practically exsanguinated when first seen. After the beneficial result of the paravertebral block was observed, it was felt that sympathectomy should be done to give maximum possible re-establishment of circulation. The possibility of thrombosis of the femoral artery, lying in an open wound susceptible to infection, was considered a further indication. It should be noted that the calf was not tense.

CASE 2. American soldier, aged 25 years, sustained a gunshot wound at 11:00 a.m., December 20, 1943. He arrived at the field hospital about 10 hours after injury. On examination he was found to be in severe shock. He had a perforating wound of the right buttock and a small penetrating wound in the region of Scarpa's triangle on the right. The popliteal and dorsalis pedis pulses on the right were unobtainable. The calf was not tense. X-ray examination showed a fracture of the coccyx and a bullet near the head of the right femur. On digital examination a tear of the rectum was found.

At 11:45 p.m. operation was commenced. A loop sigmoidostomy was done, and extensive débridement of the buttock wound was performed, with closure of the rectal tear and resection of the coccyx. The femoral artery and vein were exposed at the profunda area. A hematoma in the wall of the artery was evacuated by a longitudinal incision which was then closed. The adventitia was stripped from the wall of the artery for a distance of 6 inches so as to perform periarterial sympathectomy. Pulsations were observed below the stripped area, which was distal to the profunda branch. The leg was put in extension in a Keller-Blake splint.

On December 21 it was noted that the foot was cold and blanched, and the dorsalis pedis pulse was not palpable. A ganglionectomy was advised and performed at 8:00 p.m. The Smithwick approach was used and found particularly convenient because of the presence of the colostomy. The 2d and 3d ganglia with intervening nerve were removed. Following operation there was no discernible change in the appearance of the foot.

On December 23 the leg was warm to the ankle but the foot remained cold. The patient was evacuated a few days later, without improvement in the circulation of the foot. On January 5, 1944, in a general hospital a guillotine lower leg amputation was done, leaving a tibial stump of about 7 inches.

In the light of subsequent observations, we feel that sympathectomy was performed too late in this case to be of maximum benefit. The procedure may have saved the knee. It is possible that this man suffered embolism from the traumatized femoral artery.

CASE 3. American soldier, aged 22 years, was wounded in action by shell fragment at 4:00 p.m., December 23, 1943. He arrived in the field hospital about 3 hours after wounding. When first seen he was in a marked degree of shock. Blood pressure and pulse were imperceptible. There was a small, penetrating wound in the upper portion of the right thigh anteriorly. A tourniquet was in place and was adequate to control hemorrhage, which had apparently been most severe. Shock therapy with blood and plasma was immediately instituted. More detailed examination of the right leg revealed that the calf was firm, tense, and tender, even though there was no wound below the groin, and his injury was only

3 to 4 hours old. There were no pulses below the groin, even when the tourniquet was removed.

At 9:30 p.m. operation was commenced. The femoral region was explored through a vertical incision incorporating the original wound of entry. Digital pressure by the assistant was necessary at all times to control severe hemorrhage. The femoral artery was completely torn just below the origin of the profunda. The medial femoral circumflex artery and the femoral and profunda veins were also entirely severed. The foreign body was removed, and all vessel ends ligated with silk. Following control of the hemorrhage, the only patent artery in the region was the profunda femoris. The lateral femoral circumflex artery was not visualized, but there was no indication of trauma to this vessel and it was assumed to be intact. Extreme care was taken not to clamp any undamaged vessels and this error was fortunately avoided. The fascia was closed over the vessels, and the wound otherwise left open. The patient was then turned on his left side and lumbar ganglionectomy performed utilizing Smithwick's lumbar incision. The 2d and 3d ganglia and intervening chain were removed. Following operation there was no apparent change in the appearance of the leg or foot. A heavily padded cast was applied and immediately bivalved.

On December 22 leg was warm to 8 inches below the knee. The calf remained tense and tender, and the foot was colder than the left. On December 27, there was early demarcation at junction of mid and lower thirds of the lower leg. On January 3 guillotine amputation, right supracondylar, was performed under ether anesthesia.

We now believe that lower leg fasciotomy should have been done in addition to ganglionectomy. This man was in most severe shock due to extreme blood loss. Nevertheless with appropriate replacement therapy he tolerated a difficult and lengthy procedure at the site of injury, and sympathectomy as well. His condition after operation was most satisfactory.

CASE 4. American soldier, aged 28 years, was wounded by an antipersonnel mine at 6:30 p.m. on December 24, 1943. He was brought to the field hospital about 15 hours after injury. On examination he was found to have multiple perforating and penetrating wounds of both arms and legs, compound fracture of the left fibula, and absent pulses in the left foot and the left wrist. We were asked to see the patient in consultation during the time that débridement of the wounds was being performed, and it was agreed that a left lumbar ganglionectomy was indicated. This procedure was decided upon because of the presence of a perforating wound in the lower portion of the left popliteal space and a blanched, cold, and pulseless left foot.

Operation was performed at 11:00 a.m. December 25. At the first part of the operation, performed by another surgeon, all wounds were débrided and foreign bodies removed. The left popliteal artery was visualized at its bifurcation and observed to be intact. However, there was spasm of the anterior and posterior tibial arteries. The left brachial artery was found to be lacerated in its midportion and was divided and ligated.

Following these procedures, there was no change in the appearance of the left leg. (The left hand appeared quite viable.) At this point one of us entered the operation and performed left lumbar ganglionectomy through a left lower quadrant, gridiron incision. The 2d and 3d ganglia and intervening chain were resected. A heavily padded cast was applied to the leg. There was moderate but definite improvement in appearance of the leg after this operation.

On December 26 gas infection became apparent in the region of the left knee, and a mid-thigh amputation was performed.

Recovery was uneventful after amputation, and the patient was evacuated on January 2, 1944.

Examination of the amputated leg showed the posterior tibial and peroneal arteries to be torn. We believed that sympathectomy was indicated because of a wound affecting the region of the popliteal artery, and that removal of the ganglia was a surer means of obtaining the desired result than injection. It is of interest that this man's left arm survived in face of ligation of the brachial artery, without sympathectomy or dorsal procaine injection.

CASE 5. American soldier, aged 22 years, received gunshot wounds at 11:30 a.m. on March 1, 1944. On arrival in the field hospital he was found to have a traumatic amputation of the left forefinger and a penetrating wound of the medial aspect of the right thigh in its lower third. The right foot was cold and pulseless. There was no fracture. The calf was not tense, bleeding was moderate, and he was in moderate shock.

Amputation of the finger was completed at 7:30 p.m. The wound of entry of the thigh was débrided and the femoral artery was found so severely torn in the lower third as to preclude repair. The vessel was ligated. Following this procedure, a right lumbar ganglionectomy was done through a large gridiron incision in the right lower quadrant, by an extraperitoneal approach. The 2d and 3d ganglia with the intervening chain were removed.

Examination on March 3 showed that foot was warm and blanched on pressure. There was no pulse perceptible in the foot.

The patient made a good recovery and was evacuated a week after operation. Follow-up in 6 weeks reported that he was ambulatory, having no difficulty with the leg, and that he had no edema at any time.

We believe that sympathectomy perhaps saved this extremity. It is to be noted that the calf was not tense. The case was favorable in that operation was performed 8 hours following injury.

CASE 6. American soldier, aged 23 years, was wounded in action by artillery fragments at 3:00 a.m., March 16, 1944. He was admitted to the field hospital approximately 4 hours after injury. Examination disclosed that he had multiple penetrating wounds of the right thigh and leg, left arm and leg, and left chest wall. The right calf was tense, and the foot was pulseless. However, the foot was not blanched and though cooler than the left was not stone cold. There was no fracture. The patient was not in severe shock.

At 9:50 a.m. March 16, operation was undertaken; all wounds were débrided and all foreign bodies removed. The right femoral artery was found to be severed for about three-fourths of its circumference in its lower third, and suture was not feasible because of the extent of the trauma. The artery was divided and ligated with silk. The femoral vein was intact and was not ligated. The foot was cold and blanched at the end of this procedure. A right lumbar ganglionectomy was then performed through a lateral, extraperitoneal, gridiron incision. The 2d and 3d ganglia and intervening nerve were resected. The leg was placed in a bivalved, heavily padded cast. The right leg and foot were warm for about 12 hours after sympathectomy but were never as warm as the left, and the effect gradually disappeared. On March 19 the foot was cold, and mottling was beginning to appear. On March 21 there was severe pain in the leg and foot, which was cold and mottled from the ankle down. Calf muscles were swollen and there was pitting edema of the skin. The wound was clean. There was no evidence of gas gangrene. At 4:00 p.m. supracondylar, guillotine amputation of the right leg was carried out.

Subsequent to amputation the patient did well and was evacuated improved.

This case should be compared with the preceding. Both were seen relatively early. The injuries were similar and at approximately the same level. Neither patient had lost an extreme amount of blood. The outstanding difference was in the presence of a tight calf in Case 6. We now feel that the addition of a fasciotomy might well have saved the leg.

CASE 7. Soldier, aged 22 years, was wounded by a shell fragment at 4:00 a.m. January 24, 1944. On arrival at the field hospital some 12 hours later he was found to be suffering from a perforating wound of the lower third of the right thigh, with a compound comminuted fracture of the femur. He was in mild shock and was not bleeding. His general condition was described as fair. No note was made concerning pulses of foot or condition of calf.

At 6:00 p.m. the same day, operation was performed. Wounds of entry and exit were débrided. The vessels were apparently not visualized. A Tobruk type splint was applied and immediately split widely because of lack of circulation in the foot. The postoperative diagnosis was compound comminuted fracture of the right femur in its lower third with possible damage to the vessels of the thigh and ischemia of the foot.

On January 25 at 8:00 p.m. we were asked to see the patient in consultation. He was complaining of severe pain in the lower leg. The leg was in a widely split Tobruk splint. No pulses were palpable in the foot. The leg from midcalf to toes was mottled, cyanotic, and cold. At 10:30 p.m., some 42 hours after injury and 28 hours after the first operation, a right lumbar ganglionectomy was done through a gridiron incision in the lower quadrant. In the interval between the first operation and sympathectomy he had had three lumbar paravertebral novocain injections, with no apparent benefit. The sympathectomy was apparently of no avail, and on January 30 a mid-thigh amputation was done just above the fracture site. It was noted that the femoral artery and vein were thrombosed at the site of amputation but that collateral circulation was well developed. Course after amputation was uneventful and on February 4 the patient was evacuated.

We believe that sympathectomy this late following injury is of no avail. When patient was first seen the damage was irreparable and loss of the leg inevitable. Under these circumstances in the future, we should not perform sympathectomy.

CASE 8. Soldier, aged 19 years, was wounded by artillery fragments at 5:00 a.m. May 16, 1944. On arrival in the field hospital he was found to have multiple penetrating wounds of the right arm and leg, compound comminuted fracture of the right humerus, and compound comminuted fractures of the right tibia and fibula. There was impaired circulation in the right foot: the member was cold and cyanotic distal to a line about 4 inches above the ankle and there were no pulses palpable.

At 3:00 a.m., May 7, all wounds were débrided. A plaster body cast was applied for the fracture of the right humerus. A circular plaster was applied to the right leg from toes to mid-thigh. It was noted that after application of the plaster the circulation in foot improved. Lumbar sympathetic block was considered but not done when circulation improved.

At 1:00 p.m. May 7, the toes of the right foot were found to be bluish. The distal portion of the leg was mottled, cyanotic, and cold, and no pulses were present in the foot. The calf was tense. The patient had had two lumbar paravertebral injections of procaine since his first operation. It was decided to do

sympathectomy, and this was performed at 2:00 p.m. by utilizing the lower quadrant, gridiron incision. No benefit was noted from this procedure. At 5:00 p.m. May 7 gas gangrene was found to be present in the leg, and a mid-thigh amputation was done under ether.

Following amputation, recovery was good.

The remarks made in comment on Case 7 apply equally here.

CASE 9. British officer, aged 26 years, was wounded by a spent machine-gun bullet at 9:00 a.m. on November 9, 1943, receiving a penetrating wound of the left thigh. At the time he was wounded he had been lying in a muddy slit trench for 48 hours and had been without food during that time. Shortly after receiving the bullet wound he was hit again, this time by a hand grenade which burst close to his trench and caused a penetrating wound of the right eye. He lay where he was hit for about 24 hours. He reached the casualty clearing station some 34 hours after being first wounded. At that time he was mildly acidotic, in slight shock (blood pressure 100/70), and not bleeding. A small penetrating wound was present in the mid-portion of the left thigh posteriorly. The missile was palpable subcutaneously anteriorly. Pulses were present in foot.

Operation was performed at 8:00 p.m. on November 10. The foreign body in the leg was removed through an anterior counterincision. The wound of entry was enlarged and débrided. The femoral vein was torn but the artery was intact. The vein was ligated with silk. The artery was visibly and palpably in marked spasm. However, feeble pulsations were seen to come through and the spasm to relax at the end of the operation. During the operation there was difficulty controlling bleeding from the vein and avoiding injury to the intact artery and sciatic nerve. The patient lost a considerable quantity of blood and required the administration of blood and plasma during the operation. When the procedure was completed, a paravertebral procaine injection of 10 cubic centimeters in the region of 2d and 3d lumbar ganglia was done with some warming of the calf resulting, but no pulses were palpable in the foot. His general condition appeared fairly good, pulse was 130 but of good quality, and blood pressure was normal at the time of return to the ward.

At midnight of the day of operation his radial pulse was good. The foot, however, was cold, cyanotic, and pulseless. The patient was not yet recovered from the anesthetic. Early the following morning he became disoriented, pulse became rapid, and blood pressure fell. There was no evidence of gas infection. In spite of vigorous supportive measures, he failed to recover and died at 10:00 a.m. November 12.

Autopsy was unfortunately not possible. He may have died of blast injury due to the very close explosion of the hand grenade. He had terminal anuria, and death may have been due to transfusion reaction. It is certain that he was in a more precarious physiological state at the time of operation than was fully appreciated, and though he was compensated when the operation was started it took the loss of only a relatively small amount of blood to precipitate shock during the procedure.

The effect of paravertebral block in this patient was definite, though not completely satisfactory in that restoration of circulation to the foot was not effected. It is possible that had he not suffered from severe peripheral vascular collapse, repeated lumbar block might have permanently relieved the arterial spasm. Repetition of the block or sympathectomy was contemplated, the choice between the procedures to depend on the condition of the foot 8 hours after operation. However, the patient's collapse demanded that all efforts be directed at saving his life. This we were unfortunately not able to do.

EVALUATION

In reviewing these histories, it becomes apparent that in Cases 2, 7, and 8, too much time was lost between injury and sympathectomy for the latter to be of benefit. As the summaries of these 3 cases show, the lower leg in each appeared nonviable at the time of ganglionectomy. If sympathectomy is to be done, it should be done as early as possible, that is, at the time of the original operation for the injuries. From our experience with these 3 cases it would seem hardly worth while to employ sympathectomy in patients in whom the limb is already clinically nonviable.

A condition commonly seen in lower extremities with acutely impaired circulation is the so called "tight calf." This condition was observed in 2 cases (3 and 6). In neither were the wounds so situated as to cause hematoma of the calf. It is thought that tight calf is due to a cloudy swelling of the muscles due to anoxia., The condition can arise early (Case 3). We feel that in such cases one may postulate that sympathectomy without extensive lower leg fasciotomy is useless. Unfortunately, we failed to employ fasciotomy in these 2 patients. Whether or not the legs would have survived had we used a combination of sympathectomy and fasciotomy we do not know, but we strongly urge a combination of the

two procedures and intend to employ the combination in such cases in the future. Tense calf muscles are seen sufficiently often so that one should always examine the lower leg in these patients to determine the presence or absence of tension.

In wounds of the lower leg, hematoma frequently comprises circulation distal to the point of trauma. Extensive fasciotomy without sympathectomy has been employed by us in such cases and found sufficient to save the leg even when two of the three major vascular bundles were severed. When the condition of the patient with such an injury has permitted the use of spinal anesthesia, we have felt that the temporary interruption of vasoconstrictor impulses has been beneficial. This property of spinal anesthesia should be kept in mind, and its employment in carefully selected cases may prove advantageous.

We believe that certain indications for the performance of ganglionectomy may be proposed. The possible benefit to be derived from the procedure should be considered in the management of any traumatized extremity presenting evidence of vascular impairment. Points to be searched for in examination of the patient are the absence of pulses in the foot and popliteal space, a leg colder than the normal one, blanching, cyanosis, or mottling of the foot or leg, early loss of cutaneous tactile sensibility, and the presence of a tight calf. The presence of any of the foregoing conditions should serve as a warning that serious vascular damage exists, and usually several of them will be found in the same extremity. The presence of tight calf we believe to be of particular significance, indicating as it does a serious degree of anoxia.

Given any of the physical findings mentioned, it is imperative that at operation upon the wounds the surgeon visualize and completely understand the exact nature and extent of the vascular injury. In the majority of patients presenting the signs we have mentioned, either direct injury or severe spasm (or both) of a major vessel is almost certainly present. If damage to a major vessel is found in a patient presenting these signs, we believe that sympathectomy should be done. If spasm alone is found, paravertebral block should first be tried and may well prove adequate. Should the patient's other wounds make it apparent that repeated blocks will be arduous for him, sympathectomy should be done at the first sitting.

We believe that the patient's chances will be favored if ganglionectomy is done in all wounds to the iliac, femoral, or popliteal arteries, and in patients with wounds of the thigh who present a tight calf. Sympathectomy should be considered as a prophylactic measure in dealing with wounds to major vessels (e.g. the superficial femoral artery) if the circulation is not grossly impaired.

There are certain contraindications to ganglionectomy. It will obviously serve no useful purpose in limbs so severely traumatized that primary amputation is necessary. If the patient is seen late following wounding, the likelihood is that sympathectomy will do no good. In general, if a limb appears nonviable and changes are at all advanced, with a beginning line of skin demarcation, sympathectomy will probably be useless. Our earlier hope that the operation even in these cases might save a part of the limb and make possible a lower amputation has perhaps been borne out in 1 instance (Case 2). In patients in whom the time element is borderline, it might be well to perform paravertebral block, and base the final decision for or against ganglionectomy on the observed effect (Case 9).

It will be appreciated that great attention to detail is necessary in the handling of the type of injury under discussion. The dressing is particularly important. We have found that a satisfactory method of protecting an extremity with precarious circulation is to wrap the member in an extra thick layer of cotton from toes to groin, and to incorporate it in a light circular plaster cast with a firm posterior splint. Then the entire cast and padding must be bivalved. Examination of the leg can be made simply by removing the top shell. The object of such a dressing is to give an even distribution of pressure and thereby prevent pressure points and necrosis.

A word should be said with regard to the use of dorsal sympathectomy for injury to the vessels of the arm. We have seen no case, either of our own or of our associates in which

this procedure appeared indicated. As one would expect, the collateral circulation in the arm is practically always adequate to assure viability (e.g., Case 4). Patients we have seen with vascular trauma sufficient to jeopardize the limb have all required amputation because of the extent of the damage to other parts. A rare case may be seen in which this condition is not so, and for this dorsal ganglionectomy should be kept in mind.

Two points must be finally emphasized. First, ganglionectomy to be of benefit must be performed early; it is probable that after 24 hours tissue damage is irreversible. Second, ganglionectomy is an adjunct only in the management of these wounds. Thorough débridement with meticulous care for the structure involved, complete visualization of the pathology, and attention to detail in dressing are imperative. Supplementary procedures must be performed as indicated; fasciotomy for tight calf may be cited.

TECHNIQUE

The rationale of the operation of ganglionectomy lies in the fact that when the central vasoconstrictor impulses to a vessel are interrupted, maximal relaxation of the arterial smooth muscle results. It has been further demonstrated that the most permanent and complete results are obtained by a procedure which interrupts preganglionic fibers only. This is accomplished satisfactorily in the case of the lower extremity by removal of the second and third lumbar sympathetic ganglia (1).

We have employed an extraperitoneal approach to the lumbar gangliated chain in all cases. Three were done through the flank approach advocated by Smithwick, the others through the large, lower quadrant gridiron incision of Leriche. We have found that the approach of Smithwick is most convenient in small patients and in those in whom the presence of other wounds made the gridiron incision impractical (Case 2). It has been found, however, that if one does not have available certain instruments, particularly Deaver retractors longer that those in standard use by the Army, Crile nerve hooks, Hartman forceps, Cameron light, and a long dura clip carrier, that the operation is technically difficult due to the depth of the wound. It is also impossible to place the patient in optimum position for this approach on the operating tables available in the field. Therefore, we advocate the lower quadrant gridiron incision for the usual case done in forward hospitals.

The transperitoneal approach, which we have not used, might prove the most feasible in patients requiring laparotomy and sympathectomy. We have had one such patient, in whom the missile after penetrating the groin perforated the right external iliac artery and passed upward causing extensive visceral damage. Transperitoneal sympathectomy through the laparotomy incision would have been performed on this patient had he survived his massive hemorrhage and intraperitoneal damage.

SUMMARY

It is our opinion that lumbar ganglionectomy, if it can be performed early, should be considered in the management of wounds from the bifurcation of the aorta to the bifurcation of the popliteal artery which jeopardize the circulation to the lower extremity. The real test may lie in its use in cases of severed popliteal artery, for very few extremities survive with injury to this vessel. Presence of an intact profunda femoris artery in the face of loss of the superficial femoral has been found to be no guarantee of the viability of the extremity. Collateral circulation of the lower leg has been found to be sufficient even in the presence of ligation of two of the three major vessels. It is felt that ganglionectomy will be less frequently indicated in injuries to vessels of the lower leg than in those of the thigh.

It is our hope that this paper will stimulate the interest of others in the use of ganglionectomy as an adjunct to treatment of wounds of the major peripheral blood vessels, and that their results will be reported. Thereby the true value and place of the procedure in treatment of this class of wounds may be established.

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ASEPTIC GASTRIC RESECTION

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NEARLY forty years elapsed between Souligoux's proposed technique of gastroenterostomy and the present method of gastric resection with closed aseptic anastomosis. The latter has been advocated by Wangensteen, Babcock, Totten, Holman, Weinsten, Emerson, Neuber, and Monteiro.

It is interesting to review the technique which avoids opening the stomach and intestinal cavities at the time of anastomosis. Briefly stated, it is as follows:

1. With a special forceps the portions of the stomach and intestine where the anastomostic opening is to be made are crushed. This crushing traumatizes particularly the mucosa and muscularis, and has the least effect on the serosa.

2. Caustic potash is applied to that portion of the gastric and intestinal serosa demarcated by the blades of the forceps.

3. A seromuscular suture is made around the crushed and causticized area. After 48 hours, when this tissue sphacelates, the anastomotic opening is sealed off without contamination by coalescence of the serosas held in apposition by the sutures.

Gudin, Wadhams, Luquet, and others have contributed much to the development of aseptic gastrointestinal anastomosis. Wadhams and Luquet advocated electrocoagulation of the walls of the stomach and intestine followed by seromuscular sutures around the electrocoagulated area such that when the eschar separated there was already coalescence of the serosas and the opening was established without contamination. This is essentially the principle advocated by Souligoux.

Closed intestinal anastomosis has been popular since Doyen, in 1897, in an effort to effect hemostasis, established the principle of crushing the intestine in order to close it aseptically. With his "angiotribe" the intestine was reduced to paper thinness. With his procedure contamination from intestinal contents was avoided, and its use was advocated in end-to-end anastomosis: ligating the crushed ends; bringing them to apposition with seromuscular sutures; cutting the ligature with scissors introduced through the opening just before completing the encircling sutures.

The method of Doyen was followed by various means of closed anastomosis differing only in minor details. Some surgeons have given preference to anastomotic clamps, others to traction sutures.

It is not in the scope of this paper to discuss all the various methods of closed intestinal anastomosis. The closed method of intestinal anastomosis was worked out at our clinic while the open anastomosis for the stomach was still in use; hemorrhage was feared if the mucosa was not sutured. The few immediate and late bad results were accepted because of the 80 per cent good results.

In 1918 Gudin, in discussing "asepsis and hemostasis of gastrointestinal surgery," reported his first failure in aseptic gastrectomy. In 1939 and again in 1941, Gudin presented in Rio de Janeiro and in Buenos Aires motion pictures illustrating his technique of gastrectomy with closed anastomosis. Before the National Academy of Medicine in 1943 he presented a paper in which he brought forward the value of what he termed "lamination." He presented his own instrument which he believed insured hemostasis, and at the same time he emphasized the importance of using traction sutures, as recommended by Pauchet, instead of anastomotic clamps. He believed that his method was a further improvement in gastrointestinal surgery.

Since 1935 the von Petz (5) suture instrument has been used in our clinic to close the duodenum in gastroenterostomies and also to close the large bowel after surgery. In typical subtotal gastrectomies the technique of Reichel-Pólya as developed by Montenegro has been continued. When the von Petz suture

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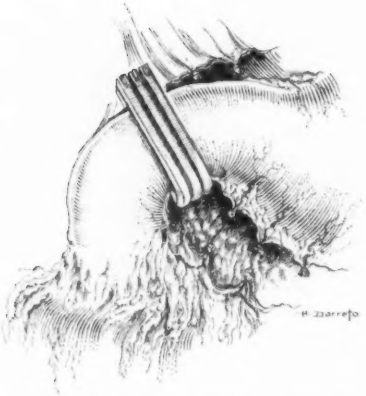

Fig. 1. Aseptic gastrectomy. Crushing of the duodenum with De Martel's clamps.

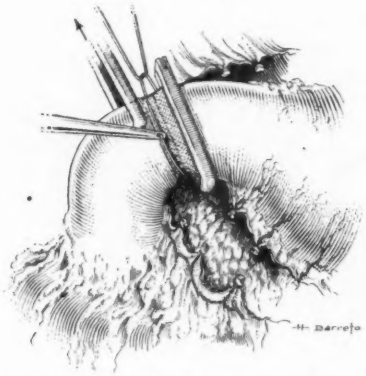

Fig. 2. The center blade of the clamp was removed to show the crushed zone.

instrument is used, the technique of Hoffmeister-Finsterer is followed; the clips from the segment of the stomach to be anastomosed are removed and the operation is finished by the open method.

In the beginning of 1943 the technique to be described was devised. It was decided to apply the closed method of anastomosis in gastric resections for the following reasons: (1) the reliability of the closure of the von Petz suture instrument; (2) the assurance of hemostasis by electrocoagulation; (3) the good results of closed aseptic anastomosis in bowel surgery; (4) the good results obtained in our experiments in dogs; and (5) the opinion of other experienced surgeons voiced in recent publications—Wangensteen, Babcock, Totten, and Holman.

In 1943, 2 gastric resections were performed by the new technique in Buenos Aires. After witnessing the operations, Prof. Galindez remarked that the technique was revolutionary. It is our opinion that it is evolutionary, rather than revolutionary, because it merely advances one more step the technique of closed anastomosis of the gastrointestinal tract. It

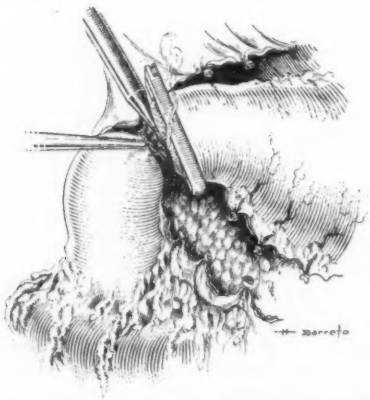

Fig. 3. Two ties are placed on the crushed portion of the duodenum. We see one going through the orifice in the Barreto's guillotine.

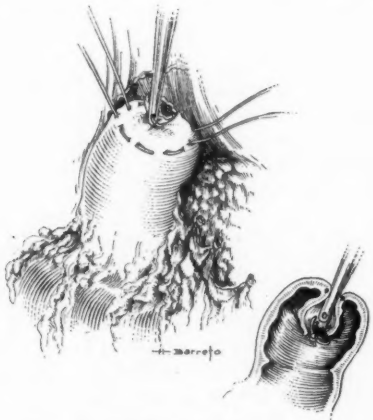

Fig. 4. The stump of the duodenum is buried with a pursestring suture. In the inset we see how the guillotine has cut the tying suture to avoid closed septic cavity.

is my belief that the present technique of anastomosis insures asepsis simply because the sutures do not pass through all coats. Sutures that do pass through all coats act as drains from the cavity of the gastrointestinal tract into the subserosal space.

The absence of edema about the anastomosis eases the postoperative course to such an extent that there is no need for the employment of the Abbot-Rawson tube. It is impressive when the postoperative course following this technique is compared with that following open anastomosis.

While the perfect method of aseptic gastrectomy has not been developed we do appear to have arrived at a safe technique that brings excellent results. On the basis of the results in 40 cases in which patients were carefully followed it is believed that this new technique can be recommended. It is possible that further improvement in technique will include the use of a special insulated clamp that will permit the employment of an electric cautery after the completion of the seromuscular suture.

Another problem we hope to solve is how to deal with terebrant duodenal ulcers, while adhering to principle of closed aseptic surgery. Up to the present time submucous separation has been done according to the method of Montenegro, which seems preferable to the technique of Nissen. This very interesting subject will be discussed in another article which is soon to be published and in which will be considered the question of whether or

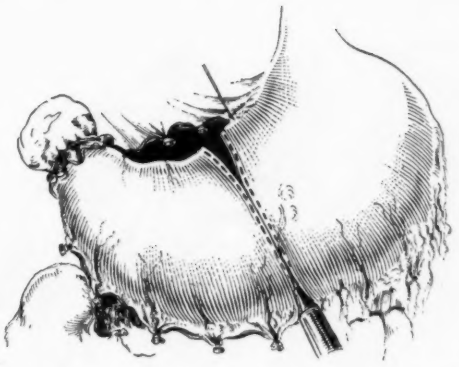

Fig. 5. The pyloric end of the stomach is protected with a rubber cap. The Monteiro sewing clamp has been applied to the stomach. The stomach is being sectioned between the two rows of Monteiro's clips.

Fig. 6.

Fig. 6. The Monteiro special clamp is applied on the segment of the stomach that is going to be anastomosed with the jejunum.

Fig. 7.

Fig. 7. Closure of superior third of the stomach section is being accomplished by means of Halsted's stitches burying the clips.

Fig. 8.

Fig. 8. The clips on the portion to be anastomosed are removed with the electric knife.

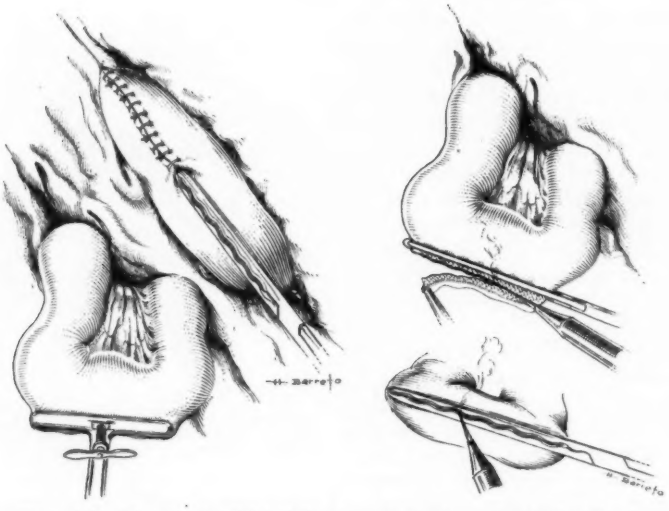

Fig. 9, left. The superior third of the stomach has been closed; the clips have been removed from the lower two thirds. The jejunum is being crushed, the crushing clamp of Gudin being used.

Fig. 10. The Monteiro clamp applied to the region of crushed area of the jejunum and the excess of crushed tissue being removed with the electric knife. The lower figure shows electrocoagulation of the cut margin of jejunum, the same procedure we use for the stomach after the clips are removed.

not terebrant ulcers of the duodenum should be removed and also how to proceed with this step without interfering with the aseptic technique.

TECHNIQUE IN GASTROENTEROSTOMY

1. The blood vessels of the greater curvature are ligated either above or below the great arterial circle in case an ulcer is present and always below in case a malignant growth is present.

2. The pyloric and gastric arteries are transfixed and doubly ligated.

3. The duodenal stump is closed in the following manner:

a. The stump is crushed with De Martel's clamp and tied with a temporary ligature that is cut with Barreto's guillotine after the stump has been inverted by means of a pursestring suture.

b. A von Petz (5) clamp is applied followed by inversion of the stump with a pursestring suture or with the Halsted's quilt suture.

TECHNIQUE IN GASTROJEJUNAL ANASTOMOSIS

After the von Petz suture instrument is applied to the stomach at the level to be removed, the clips are compressed and a special clamp of my own design is applied just above the proximal row of clips. By means of an electric scalpel the stomach is severed between the two rows of clips, thus removing the distal segment. Two types of clamps of my own design are used; the larger one for the Reichel-Pólya anastomosis, the smaller for the Hoffmeister-Finsterer type, the latter being preferable. The clips remain on the portion of the stomach which is not to be used in the anastomosis and are buried with Halsted's quilt suture.

A jejunal loop about 20 inches in length is selected for antecolic anastomosis. The portion to be anastomosed is crushed with the "T laminator" clamp of Gudin, then removed and one of my own clamps is applied. The jejunum is approximated to the stomach, and under the clamp the posterior seromuscular suture is made. This suture begins at the

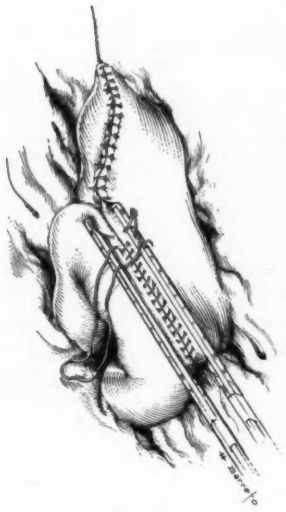

Fig. 11.

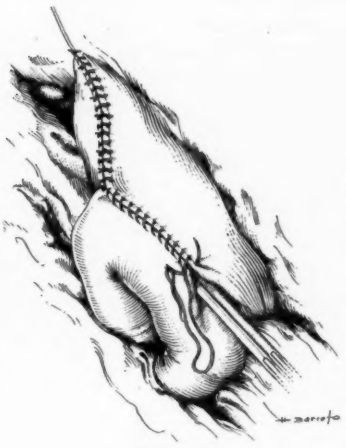

Fig. 12.

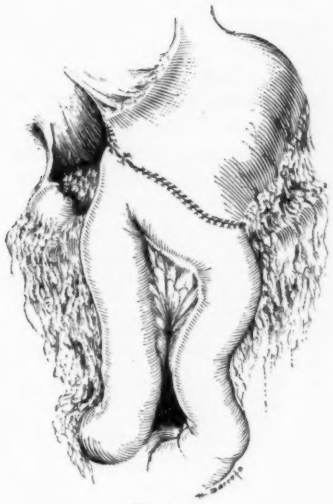

Fig. 13.

Fig. 11. Seromuscular suture between the stomach and jejunum falls below the clamps.

Fig. 12. The seromuscular suture is carried over the clamps to the anterior wall down to the base of the clamps. The clamps are removed then and the suture is completed.

Fig. 13. After the seromuscular suture is completed all around, a few reinforced interrupted sutures are applied on the anterior and posterior wall and at the angles.

base of the clamp and extends up to the tip of the clamp. The excess of crushed jejunum is removed and also the distal row of von Petz's (5) clamp from the stomach.

The cut edges of the stomach and jejunum are lightly electrocoagulated. This done, the seromuscular suture is continued around the tips of the clamps and above them until their base is reached. At this point the clamp is removed and the suture is completed by closing the fenestration which has been caused by its removal.

The efferent loop of the jejunum is then buttressed over the suture line of that portion of the stomach not used in the anastomosis. A few reinforcing interrupted sutures are applied at the angles and around the circumference of the anastomosis to complete the operation. The anastomosis is made patulous immediately by the employment of the thumb and forefinger from the outside.

COMMENTS

The method of aseptic gastric resection here described has been found most satisfactory. With it, it is possible to avoid filiform drainage along the sutures from the mucosa. This drainage, with contamination, is inevitable if the sutures run through all layers of the stomach or bowel.

The von Petz (5) and similar clamps have been found most useful in carrying out the procedure, but they can be dispensed with when the electric scalpel and the so called "laminator," the crushing clamp, are used. Slow and gradual crushing alone, even if prolonged for one hour, does not guarantee hemostasis.

That certain terebrating ulcers are not satisfactorily handled by crushing should not prevent the use of closed anastomosis where indicated, any more than should the occurrence of perforated ulcers. Nor is one justified, in my opinion, in advocating open resection for gastric ulcers and closed anastomosis for carcinoma.

SUMMARY

An improvement in the technique of aseptic gastrectomy is described. The technique has been used in 40 cases of ulcer with 1 death; this death was not the result of faulty technique.

The technique described might have been adopted earlier had I not felt satisfied with 80 per cent good results and fear of hemorrhage. Only after becoming confident of hemostasis by crushing and electrocoagulation or ligature of the submucosal vessels through experiments on dogs, was the decision made to abandon the mucosal suture and to adopt this new technique.

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SUCKING WOUNDS OF THE CHEST

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SUCKING wounds of the chest are met commonly among the seriously wounded casualties admitted to an evacuation hospital. While they are encountered seldom in civil practice and infrequently in military hospitals not in the field, we believe that our experiences in dealing with them may be of interest to surgeons engaged in war surgery in forward hospital units and to others doing secondary thoracic operations for the late complications. This communication will deal with the preoperative, operative, and postoperative management of patients with open wounds of the thorax up until the time that those who recover are well enough to be evacuated to the rear. This echelon of surgical treatment is today a field in itself. Only the immediate results can be presented since the end-results in this group of cases cannot be known for some time.

During a 3 month period 70 patients with sucking wounds of the chest were treated in an evacuation hospital during a very busy period. These patients represented 8.1 per cent of a total of 859 casualties with injuries of the thorax. Of this group 315, or 36.7 per cent, were known to have hemothorax, pneumothorax, or both. This figure undoubtedly would have been larger if conditions had permitted more complete study. The progressively increasing dangers associated with open pneumothorax, however, made the sucking wound group the greatest problem. Shock, mediastinal flutter with interference with cardiac action, anoxia from ineffectual respiration, loss of body fluid and heat, and infection of the pleural cavity are some of the particular hazards encountered.

DIAGNOSIS

The diagnosis of an open chest wound had usually been made at a forward installation and an occlusive vaseline gauze dressing with tight adhesive strapping applied. In some cases, however, the diagnosis had been missed, and a sucking wound would be found under the original blood soaked battle dressing. In only 1 of our cases had emergency suture been performed; and, incidentally, this proved to be ineffective. A properly applied vaseline gauze dressing was nearly always adequate. On admission of patients with chest wounds an inspection of the dressing was made at once on the shock ward or in the preoperative wards, and the patient was asked to cough unless the diagnosis of open pleural communication was obvious. A gush of air or blood on coughing occurred in positive cases not previously detected. A good occlusive dressing was then applied.

Of equal importance and perhaps of more importance than the diagnosis of the open pneumothorax is the question of the diagnosis of factors complicating the picture in these patients; namely, the presence or absence of shock, severe respiratory or circulatory embarrassment, hemorrhage from the lung or chest wall, injury to the mediastinal or abdominal organs, and injury to the contralateral lung. Moreover, the surgeon is interested in the number and location of fractured ribs and foreign bodies and the extent of any associated injuries which in themselves influence the various decisions he must make.

CLINICAL FINDINGS

In our group of 70 cases, 48 wounds were the result of shell fragments, 18 were incurred by machine gun or rifle bullets, and in 4 the type of missile was not stated. In 49 instances the wounds were of the penetrating type; in 20 they were perforating, i.e., through and through, and there was 1 gutter type of wound. Fractures of the ribs or costal cartilages were known to be present in 44 cases, 20 of which had multiple fractures; but the true figure was probably higher. In addition,

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fracture of the clavicle was seen in 3 cases and fracture of the scapula in 2. Right-sided wounds were nearly twice as common as left-sided; 45 of the former as compared with 23 of the latter. Presumably left-sided wounds were more frequently fatal on the battlefield. In 2 patients there were bilateral sucking wounds, and in 4 there were 2 sucking wounds on the same side. Shock was present on admission in moderate or severe degree in 37 cases. This figure would probably have been higher had not many cases received from 1 to 4 units of plasma and in a few cases blood transfusions as well at forward installations. Severe shock was, of course, more common in the sucking thoracoabdominal wounds and in large thoracic wounds with considerable bleeding. Slight to moderate dyspnea was present in two-thirds of these patients; most of whom required oxygen; and there was severe dyspnea and cyanosis in 9. Wound hemorrhage was severe in 9 cases and was important not only because of the blood loss involved, but also because it was liable to loosen the occlusive dressing and re-establish the open pneumothorax. All cases had some degree of hemothorax and pneumothorax, but the former was severe (estimated at 1000 cubic centimeters or over) in 10 cases. Only 1 instance of tension pneumothorax was found, in a patient with a valvular sucking wound at the medial end of the left clavicle. Mediastinal emphysema caused by a small laceration of the trachea was also present in this case. Another instance of moderate mediastinal emphysema occurred in a patient with perforation of the trachea which required closure and tracheotomy. On admission to the hospital pulmonary edema was well marked in 3 patients, 2 of whom died, though the condition probably occurred more frequently to a lesser degree when one considers the lung damage and paradoxical respiration commonly present in open chest wounds. Right-sided heart failure may be precipitated in such cases by the large amounts of blood and plasma used in combating shock, especially if they are given rapidly. The treatment of shock complicated by pulmonary edema is very difficult for this reason. The significance of blast injury in these cases is difficult to assess but is probably not often an important consideration. The diagnosis was made in 1 of our cases from the history and by roentgenograms. Atelectasis was diagnosed from the admission roentgenograms in 8 instances. There was homolateral partial or complete collapse of a lower lobe in 7 cases and a contralateral atelectasis of the cardiophrenic segment in the other case. In addition, densities attributed to intrapulmonary bleeding and to aspiration of blood into the bronchial tree of uninvolved portions of the lung were met with frequently. Moderate to severe gastric distention on admission was evident in 5 cases. This complication is to be watched for especially in wounds of the lower left thorax. Morphine poisoning was encountered twice; and in 1 case characterized by respiratory depression, pin-point pupils, cyanosis, and terminal convulsions, it contributed largely to the fatal outcome. One-half grain of morphine tartrate had been given hypodermically before admission in practically every case, and the familiar phenomenon of increasing morphine effect as the patient's shock improved was sometimes troublesome. The use of not over ¼ grain of morphine sulfate is recommended as the first dose in the average chest wound and no more than ⅙ grain dose subsequently. Bilateral and multiple sucking wounds have, of course, a grave prognosis. Two patients not only had 2 sucking wounds on 1 side, but also 1 sucking wound on the other hemithorax; both died. Two other men with 2 sucking wounds on the same side recovered. Associated injuries obviously have great significance, especially abdominal injuries (21 cases), severe compound fractures (16 cases), and spinal cord injuries (2 cases). Apart from abdominal injuries there were severe associated injuries in 22 patients, and slight or moderately severe wounds were present in many others.

EMERGENCY AND PREOPERATIVE CARE

All patients known to have sucking wounds were treated in the shock ward and oxygen therapy started if necessary for dyspnea and cyanosis. Patients were left on the same litter until they arrived in surgery and sometimes until they reached the postoperative

ward. The blood pressure and pulse rate were determined immediately and at frequent intervals as a guide to treatment and prognosis. Patients in shock without much dyspnea were left flat until they improved; then they were propped up in bed. Those with dyspnea were more comfortable reclining on a backrest from the outset.

A transfusion of stored citrated blood was begun as soon as possible in those showing signs of shock and hemorrhage. Even if the blood pressure was within normal limits these patients were known to have lost blood, and it was nearly the rule to give at least 2 units of plasma and 500 cubic centimeters of blood to each patient. Early in the campaign the blood was filtered into an equal quantity of normal saline or plasma for greater ease of administration. Later more transfusions of whole blood were given, especially in cases in which it was anticipated that 1000 cubic centimeters or more of blood would be necessary to lessen the likelihood of pulmonary edema from the administration of too large amounts of intravenous fluids. In 27 cases in our series one 500 cubic centimeters transfusion was given before or during surgery; in 16, 1000 cubic centimeters was given; in 24, 1500 to 2000 cubic centimeters; and in 3, 2500 cubic centimeters or more of blood was administered. Delay of blood replacement therapy until the postoperative period in cases of pulmonary bleeding has been recommended by some, but we believed that it was best to give these patients relatively large amounts of blood and plasma before and during surgery.

The injured side was kept down if there was much hemoptysis or paradoxical motion of the chest due to extensive rib fractures. Chest pain on cough or motion, or pain elsewhere due to associated injuries, was common if more than 6 hours had elapsed since the last dose of morphine. Restlessness was frequent because of pain and anoxia, so that some patients thrashed about in bed and attempted to remove the oxygen mask or catheter. Usually $\frac{1}{6}$ grain of morphine sulfate hypodermically, or $\frac{1}{8}$ grain intravenously, was given. Most patients disturbed from pain, dyspnea, anxiety, and the ambulance ride improved considerably after the first hour of rest, oxygen, blood replacement therapy, reclining posture, and sedation. Intercostal nerve blocks with 1 per cent procaine for pleuritic pain have been recommended but none was carried out in our series.

Physical examination of the chest and survey of the patient for other wounds were carried out as soon as practicable. It goes without saying that patients in severe shock should be turned as little as possible, but examination of the anterior chest may yield signs of hemothorax, pneumothorax, mediastinal deviation, paradoxical respiration, and subcutaneous emphysema.

Tetanus toxoid was given to American wounded on admission if it had not already been administered, and tetanus antitoxin was given to other wounded. The administration of penicillin in doses of 20,000 units given intramuscularly every 4 hours was started in all cases; and sulfadiazine, 1 gram every 4 hours orally, was prescribed except when there was vomiting or suspected abdominal involvement.

Severe or progressive dyspnea and mediastinal shift necessitated aspiration of air and blood in 9 of our patients during the preoperative period. Intubation of the chest for water-seal drainage was necessary in the case of tension pneumothorax mentioned. However, there seems to be no reason to aspirate moderate sized collections of air or blood preoperatively in patients who are reasonably conditioned for surgery.

Aspiration of the stomach with a Levine tube was carried out preoperatively for dilatation in several cases and probably should have been done more often to decrease the incidence of vomiting in the period of recovery from anesthesia.

Diagnosis of abdominal involvement may be easy because of the position of the wounds of entrance or exit, presence of gastric content or bile in the chest wound drainage, hematuria, or hematemesis. The position of a retained projectile in the roentgenogram with a visualization of its course is most important in difficult cases. Muscular rigidity and tenderness are rather unreliable signs of abdominal involvement since they are common on the wounded side in injuries of the lower thorax.

For this reason anteroposterior and lateral films of the abdomen were always made when any suspicion of abdominal involvement was entertained.

When a patient was out of shock and was not uncomfortable out of oxygen, he was sent to have roentgenograms made. Anteroposterior and lateral chest films were made with the patient sitting up if possible. Occasionally it was necessary to take them with the subject reclining or supine, and sometimes even through the litter when the patient's condition was poor. In 4 cases of severe perforating wounds it was thought best to forego x-ray examination because of the condition of the patients and the obvious extent of their injuries.

While sucking chest wounds had surgical priority, it was thought that once they had been sealed and shock overcome, it was time well spent to let the circulatory and respiratory mechanisms adjust themselves to the new situation. For example, we believed that a delay after the administration of rather large amounts of blood and plasma was advisable before surgery was undertaken since another 2 or 3 hours probably have little effect in increasing the incidence of empyema and may well make the patient a better operative risk. In other instances the surgeon's hand may be forced by continued bleeding from the lung, chest wall, or liver, by the presence of evisceration of the stomach or intestine, or by large sucking defects poorly controlled by dressings.

The length of time between injury and surgery in our series of cases varied greatly for many reasons but averaged 23.5 hours. The interval between admission and surgery ranged from 1 to 36 hours and averaged 10 hours. Some delay was often unavoidable, of course, because of the scheduling of other urgent cases.

ANESTHESIA

In most cases the patient was transferred from the litter to the operating table and a slow infusion of blood or plasma started. The patient was given 1/100 grain of atropine sulfate intravenously and 1/6 grain of morphine sulfate as well if he had had none in the past several hours. No morphine was given to patients in poor condition, however. Anesthesia was induced with a mixture of nitrous oxide, oxygen and ether, with the patient supine or propped up slightly. After insertion of the endotracheal tube he was turned to the appropriate position for surgery. The anesthetist could now control respiration, the dressing could be safely removed, and the skin prepared for operation. In patients with large hemothorax, or those only recently out of shock, turning sometimes caused a sharp fall in the blood pressure; and it was at this stage that the anesthetist had to watch his patient more closely.

Of the 64 men operated upon 45 received endotracheal ether and another 6 were given an ether-oxygen mixture with the anesthesia machine. The former was preferred because of the facility of controlling respiration, insuring an airway, and aspirating blood and secretions during and after surgery. A large endotracheal tube was used without a Guedel cuff or pharyngeal packing about the tube. The positive pressure which could be exerted to reinflate the lung during closure was therefore limited. However, air was aspirated from the chest catheter for this purpose in some cases.

The anesthetist preferred to maintain a constant flow of 5 to 7 liters of oxygen a minute since this procedure seemed to give better oxygenation than the use of half a liter a minute with the closed system. Once the tube had been passed, little ether was required, and the patient was maintained in the upper plane of surgical anesthesia. During wound closure and transdiaphragmatic procedures he was kept deeper to insure quieter respiration.

Postoperatively the tracheobronchial tree was aspirated with a catheter in most instances, and in several patients in whom there was considerable secretion and atelectasis, bronchoscopic aspiration was carried out. In 1 case bronchoscopy was performed before insertion of the tube for the same reason. Patients in poor condition at the end of operation were kept on the table for an hour or more if this was feasible while the administration of oxygen and blood was continued.

While the use of sodium pentothal as an anesthetic agent is ordinarily contraindicated

in patients with anoxia or excessive tracheobronchial secretion, it was used in combination with nitrous oxide and oxygen from the machine in 10 cases. Most of these were patients with small sucking wounds in whom there was little respiratory difficulty. The method was satisfactory in this selected group and its advantage lay in the time saved. It is not recommended for thoracotomy, however.

Three patients were operated upon under local procaine anesthesia. One of these had a severe thoracoabdominal wound with evisceration of the stomach and large intestine and he was operated upon while in shock in an attempt to close the pleural and abdominal defects. In the other 2 cases there were small pleural openings which the surgeon succeeded in closing after intercostal nerve block and local infiltration.

OPERATIVE TREATMENT

Of the 70 patients with sucking wounds 64 were operated upon and 6 died without surgery. The operative treatment of this group of patients is divided into the repair of structures in the chest and abdomen and closure of the chest wall, and the operations for additional unrelated injuries. Usually all surgery can be done at once, but in severely injured patients it is sometimes wise to deal with the chest and abdominal injuries first and to postpone operations on the extremities, spine, or head for 48 hours or longer.

Three principal types of thoracic operation were performed: (1) wound débridement and closure of the chest opening; (2) thoracotomy; and (3) thoracotomy plus transdiaphragmatic exploration of the upper abdomen.

Simple débridement of the wound with or without resection of a fractured rib and closure of the thorax was performed in 25 cases. This procedure was usually followed by aspiration of the hemopneumothorax with a syringe and large needle or the intubation of the chest for closed catheter drainage. The latter is indicated if a large hemopneumothorax or established infection of the pleural cavity is present and also if there is suspicion that tension pneumothorax may develop. In 2 of our cases the chest was not intubated until 24 hours after operation when the wounds began to suck again because of inadequate closure. In 1 instance the lung reexpanded and the wound healed well after simple closed catheter drainage for 48 hours. In the other the patient had to return to the operating room for a thoractomy.

In this group the pleural opening was frequently small and intercostal; rib resection was performed in only 4 cases. Ten in all had serious associated wounds, and in 4 patients laparotomy was also performed for abdominal injury.

This procedure of wound débridement and closure of the chest opening without exploration of the thoracic cavity is most applicable to the following types of wounds: first, to small sucking defects, especially intercostal ones, where the indications for thoracotomy are not present; and second, to thoracoabdominal wounds in which the major problem is in the abdomen with little or no lung damage and which usually occur if the missile has traversed only the costophrenic sinus before entering or leaving the abdomen. Here a laparotomy may be done plus débridement and closure of the chest wound with intubation or aspiration for the hemopneumothorax.

There was 1 death among these 25 patients, an indication in most instances of the nonserious nature of the chest wounds involved rather than a recommendation of this type of operation. The patient who died had a large evisceration of the stomach and colon through the abdominal wall with a small sucking chest wound. There was considerable hemorrhage with shock. He has been referred to above as one of the 3 patients operated upon under local anesthesia.

The indications for thoracotomy, i.e., enlargement of the existing pleural opening, usually with resection of segments of one or more ribs to permit inspection and operative procedures within the pleural cavity, are considered to be as follows: (1) any large sucking wound with fractures of one or more ribs; (2) suspected diaphragmatic hernia or perforation of the upper abdomen; (3) suspected continued bleeding from the intercostal vessels, the lung, internal mammary vessels, mediastinum, or liver; (4) presence of large intrathoracic foreign bodies or indriven rib

fragments; (5) suspected wounds of the trachea, bronchi, esophagus, or heart; and (6) clotted hemothorax.

After débridement of the wound or wounds the thoracotomy incision is usually made at the site of the sucking wound parallel with the fractured rib. A posterior incision like that for a first stage thoracoplasty may be necessary for posterior wounds of the apex. A thoracotomy incision separate from the wounds of entrance or exit is in our experience seldom necessary or advisable.

Twenty-three of the 64 cases belong in this second group. Rib resection was carried out in 21 of them; and in 9, segments of more than 1 rib were removed. In the other 2 cases exploration was done through an intercostal incision. After hemostasis of the chest wall and insertion of a self-retaining retractor, blood and clots were evacuated from the pleural cavity and inspection was carried out with the aid of a lighted retractor. Lacerations of the lung were sutured in 6 cases. Suture was not thought necessary for small lacerations without any bleeding. Débridement of the pulmonary tissue, except for removal of rib fragments and other foreign material, was not performed in our series. Metallic foreign bodies were removed from the lung or pleural cavity in only 3 instances although a number of others were removed from the abdomen and chest wall. Unless a small missile (1 centimeter or less in diameter) could be easily found, no time was lost in searching for it. Larger fragments were sought for and removed if possible, and the incision in the lung sutured. Many of the wounds were perforating in type and the problem of foreign body removal was not present.

Closed catheter drainage was instituted in 20 of these 23 cases, always separate from the thoracotomy incision. A No. 18 catheter was inserted and sutured to the skin, usually in the 8th or 9th interspace posterolaterally, or sometimes in the 6th interspace laterally. Closed drainage is a safeguard against respiratory embarrassment due to accumulation of fluid and air postoperatively, breakdown of the closure, and unrecognized acute empyema, and nonre-expansion of the lung. In cases with gross contamination of the pleural cavity 60,000 to 100,000 units of penicillin were injected and the tube clamped for several hours. In some cases, especially where postoperative tension pneumothorax is probable, it may be wiser to insert anterior and posterior catheters.

Closure of the thoracotomy incision in layers was now carried out beginning with the parietal pleura and periosteum together with the intercostal muscles. It is advisable to have at least a two, and better a three, layer muscular closure. Pedicled muscle grafts from the chest wall muscles were often sutured into the pleural defects which had not been completely closed with the first continuous double suture of No. 2 chromic catgut. Additional muscle layers were then closed with interrupted sutures overlapping the first closure. Pericostal sutures were used a number of times. These were most useful in drawing together intercostal incisions but were not necessary in our experience when rib resections had been performed. The subcutaneous tissues and skin were closed with loose interrupted sutures after a mixture of sulfanilamide and penicillin powder, 4 parts to 1, had been dusted into the wound. The external wounds of entrance and exit were left open only if the skin defects were too large to close, or if the interval since wounding had been so long that infection seemed likely. Tight adhesive strapping was then applied over a vaseline gauze dressing.

There were 4 deaths in this group. Two of them were due to shock and hemorrhage immediately after operation. One man with bilateral hemothorax died of pulmonary edema 23 hours, and another 3 hours, after operation. In the latter case circulatory failure was probably precipitated by the administration of too large amounts of blood and plasma.

In the third group of 16 cases thoracotomy and transdiaphragmatic repair of upper abdominal structures were performed. Rib resection was carried out in 10 patients, 2 of whom had segments of 2 ribs removed, and in 6 of whom the incision was intercostal. Suture of lung lacerations was done in 2 cases, and removal of shell fragments from the lung in 2 instances.

The frequency of involvement of the various abdominal organs is interesting. The liver alone was involved in 8 cases, liver and kidney in 2, stomach and liver in 2, spleen and stomach in 1, spleen and kidney in 1, and the diaphragm alone with diaphragmatic hernia in 1. The other case illustrates how extensive these wounds can sometimes be. This patient had a sucking wound of the left lower chest through which gastric content was escaping. A thoracotomy was done first after resection of the 7th rib and transdiaphragmatic repair of a lacerated liver and 2 perforations of the stomach were carried out. After closure of the chest, laparotomy was performed, 12 inches of jejunum resected, and end-to-end anastomosis performed. In addition another jejunal perforation was closed and the transverse colon was exteriorized for multiple perforations. He had bile in the pleural fluid for several days but otherwise his immediate postoperative course was fairly smooth.

Five patients had a laparotomy as well as thoracotomy, but it is of interest that 11 cases could be handled adequately from the thoracic approach alone. Actually splenectomy and repair of the upper portion of the stomach are more easily performed through the chest than through the abdomen.

Six of these 16 patients with sucking thoracoabdominal wounds in whom transdiaphragmatic operation was done died after operation, 4 of them within 5 hours after surgery as a result of traumatic and operative shock. Another died 40 hours after transthoracic splenectomy and repair of a perforated stomach apparently of irreversible shock. The other death was due to anuria 8 days after nephrectomy, suture of a severe liver laceration, and closure of the open chest wound.

The subject of thoracoabdominal wounds is too large to consider in detail in this communication. To sum up, however: In the 20 patients with sucking thoracoabdominal wounds operated upon, 11 were subjected to thoracotomy and transdiaphragmatic procedures only; 5 had a thoracotomy plus laparotomy; and 4 had a laparotomy with simple closure of the chest wound and aspiration or intubation.

POSTOPERATIVE MANAGEMENT

Oxygen therapy was continued on the ward in most of these cases with supportive treatment with blood and plasma as indicated. Gastric suction was started on recovery from anesthesia in cases of diaphragmatic hernia, perforation of the stomach or intestine, or in any other case with gastric distention or vomiting. Penicillin was continued in doses of 20,000 units intramuscularly every 4 hours, usually for 5 to 7 days, along with sulfadiazine, 6 grams per day. The latter was usually omitted in nephrectomy cases and in abdominal injuries or other cases requiring gastric suction. Frequent turning, deep breathing, and cough were encouraged, and morphine injections limited to 1/6 grain doses.

The chest catheter was ordinarily removed in 48 hours after injection of 40,000 units of penicillin in 20 to 30 cubic centimeters of normal saline. Its patency was checked every 6 or 8 hours by aspirating the airway needle of the water seal bottle or, if necessary, by irrigating the catheter with a little saline solution. If there had been gross contamination of the pleural cavity with gastric content or evidence of bile in the pleural fluid, catheter drainage was maintained for about 4 days. If an empyema appears, closed drainage must be continued.

Reaccumulation of serosanguineous fluid was usual, but unless physical signs or chest films indicated a moderate effusion (i.e., greater than 200 to 250 cubic centimeters), it was not aspirated. If subsequent aspirations were necessary, penicillin in saline was introduced as before and the fluid was not replaced with air. In our series 18 patients were aspirated once postoperatively usually on the 4th or 5th postoperative day; 6 were aspirated twice; and 2 were aspirated 4 times in an attempt to re-expand the lung.

Anteroposterior and lateral chest films in the sitting position were commonly taken on the 4th or 5th day after operation except in the case of thoracoabdominal wounds where the physical signs were the guides, since it was thought best not to move these patients during the first week.

In sucking thoracic wounds, as in other wounds involving hemothorax and lung col-

lapse, early re-expansion of the lung is a prime consideration, and this was encouraged by breathing exercises and by having the patient sit up over the side of the bed several times a day on the 4th postoperative day and thereafter. The latter procedure had to be omitted in the case of patients with thoracoabdominal wounds although they could be propped up on a back rest and deep breathing encouraged.

POSTOPERATIVE COMPLICATIONS

Postoperative shock was the principal complication and cause of death. It was evident in severe degree in 9 cases. Many of these patients had been in shock on admission and had improved enough to be operated upon, but the additional factors of operative trauma and anesthesia proved to be too much for them. A few were operated upon while in shock who did not respond to treatment.

Atelectasis was first evident postoperatively in 5 cases, bronchopneumonia in 3 cases, severe pulmonary edema in 2 patients (both of whom died), and massive fatal pulmonary hemorrhage in 1 case. There were 2 instances of bronchopleural fistula; in 1 case the fistula closed after 4 days of water seal drainage and the lung had re-expanded a few days later; in the other a large pneumothorax remained in spite of repeated aspirations of air, and the lung was still collapsed when the patient was evacuated a week later.

Two cases of wound disruption due to inadequate closure and failure to intubate the pleural cavity have already been mentioned. Some wound infection appeared in 3 cases, but undoubtedly it occurred in other cases after they had left our hands since in most instances the débrided wounds had been sutured at operation. The diagnosis of frank empyema was not made in any of these patients before evacuation but it was thought that at least several patients later developed it.

Drainage of bile from the operative wound complicated liver injuries in 3 cases, and in 2 of these bile was present in the pleural cavity. In 1 case mild peritonitis was thought to be due to the presence of bile in the peritoneal cavity, and in another to contamination of the peritoneal cavity by gastric content from a perforated stomach.

Abdominal distention was troublesome in 5 cases. The use of gastric suction in many of the thoracoabdominal cases probably kept this complication at a minimum.

There were three transfusion reactions of the hemolytic type in this series. This high incidence can probably be attributed to the use of stored Type O blood without previous cross matching, and to the rather large number of multiple transfusions given. Uremia occurred in 2 patients with kidney injury. One of them had had a nephrectomy and repair of a severe laceration of the liver and diaphragm.

In addition there was a temporary toxic psychosis in 2 patients probably precipitated by pain and anoxia. A cutaneous reaction to sulfadiazine was seen in 1 case and thrombophlebitis of an arm vein after prolonged intravenous therapy in 1 case.

EVACUATION

The average period of hospitalization before evacuation in our series was 6 days but varied from 3 to 15 days depending on the individual case and the military situation. Patients with laparotomy were kept for a minimum of 10 days. Occasionally military exigencies required us to evacuate our patients sooner than we ordinarily would have done, and once we were obliged to transfer patients to the care of another hospital unit before they were ready for evacuation.

In general we kept patients with serious chest wounds for at least 6 days or more, and those with thoracoabdominal wounds for at least 10 days. It was thought that patients well enough to be evacuated at all could best be evacuated by air since the dangers of anoxia and expansion of a pneumothorax were not anticipated in air transport at low altitudes. Many of our patients were so evacuated.

RESULTS

Only the immediate results of treatment can be given since the final mortality and morbidity of these patients can be properly judged only after several months of observation. For the surgeon in the field, however, the question of immediate results is an important one. There are several factors which

affect operative mortality in these cases, among them the length of time between wounding and admission which very often depended upon the military situation, and the admission of a large number of other priority cases. The desire of the surgeon to do all he can for a badly wounded man in spite of poor response to shock therapy will increase the operative mortality. At the same time, however, such a tendency may favorably influence the overall total mortality. It is with the total mortality that we should be concerned since operative mortality varies with the estimation of operability. Experience has encouraged us to increase the operability rate. In this series 91 per cent of our patients were subjected to surgery.

Seventeen of this series of 70 patients with sucking wounds died and represent a mortality rate of 24 per cent. Six of them died without operation in from 4 to 24 hours after admission as the result of shock which did not respond to treatment. In 2 cases pulmonary edema was prominent, and in 1 case morphine poisoning appeared to be most important. The 11 postoperative deaths in the 64 patients operated upon represent an operative mortality rate of 17 per cent.

Both the general mortality rate of 13.9 per cent and operative mortality rate of 7.6 per cent were less among 245 patients with penetrating and perforating nonsucking wounds of the pleural cavity admitted during the same period. Likewise, patients with thoracoabdominal wounds without open pneumothorax had a mortality rate half that of the sucking type.

SUMMARY AND CONCLUSIONS

1. Patients with sucking wounds of the chest make up an important part of the seriously injured casualties admitted to an evacuation hospital in a combat zone. The authors' experiences with 70 such cases, including 21 with thoracoabdominal wounds, have been presented.

2. Adequate preoperative preparation, including the closure of the open pneumothorax with occlusive dressings, the treatment of shock and anoxia, and the recognition of associated abdominal injuries, is highly important.

3. Sixty-four patients were operated upon, an operability rate of 91 per cent. The indications for the various surgical procedures used have been reviewed.

4. Postoperative treatment is directed toward the correction of circulatory and respiratory disturbances, re-expansion of the lung, and prevention of infection.

5. The overall mortality rate, 24 per cent, and the operative mortality rate, 17 per cent, were higher than those for other patients with penetrating and perforating wounds of the pleural cavity.

ELECTRODIAGNOSIS BY MEANS OF PROGRESSIVE CURRENTS OF LONG DURATION

Studies on Peripheral Nerve Injuries in Man

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THE relation existing between the rate of variation in current and the minimal strength of current required to produce excitation has been investigated by physiologists for many years, since an attempt was made to study it by DuBois-Reymond in 1862. Bernstein, von Fleischl, von Kries, Fick, Schott, and Gildemeister were among the older investigators.

Such so called progressive currents as have been studied may be divided into linearly increasing, or progressive currents and exponentially increasing, or progressive currents.

Among the more recent investigators to whom more accurate methods of measurement have been available and who have studied exponentially rising currents may be mentioned; Liberson, Schriever, Delville, Cardot and Laugier, d'Hollander, Solandt, and Fabre. In these experiments the duration of rise of the exponentially increasing current to its peak was less than one second, often fifty to two hundred milliseconds. In the more recent experiments on linearly increasing, or progressive currents, the longest period, likewise, was usually less than 1 second, in the case of Lucas, 1.2 seconds. In 1907, Lucas published the results of his studies on the sciatic nerves of the toad and frog and on the sartorius muscle of the frog. He found that the minimal rate of rise, which he called the minimal current gradient, in the case of the toad was of such an order that the liminal strength at instantaneous stimulation would have to be increased 46 times at the end of a second to produce an effective stimulus; for the sciatic nerve of a frog, the minimal strength at instantaneous stimulation would have to be increased 63 times at the end of a second to be an effective stimulus. Among his conclusions is the following statement:

"It is found that as current gradient is decreased, the current strength required for excitation increases more and more rapidly until a definite minimal gradient is reached. No gradient less steep than this will excite."

The belief that progressive currents possessing less than a minimal rate of rise will not stimulate even though they finally reach a considerable value was likewise expressed by Hill. From Lucas' experiments, Blair reached the conclusion that "when the gradient is too low for the rheobase to be effective no voltage is effective."

In an analysis of Solandt's data obtained from stimulation of the frog's sciatic nerve with exponentially rising currents, it may be seen that with a minimal gradient the current increases at a rate such that a value 16.7 times the rheobase value is reached in 0.27 second.

In a former publication, some of us (23) showed that when progressive currents of long duration, 1.2, 2.6, 3.8 and 8.8 seconds are used as stimuli for normal cat muscle, we were unable to confirm the existence of this liminal gradient. In the case of the normal muscle, the liminal current at instantaneous stimulation, or the rheobase, was 0.4 milliampere; at 1.2 seconds the current was 0.8 milliampere, or twice the rheobase; at 2.6 seconds, 1.05 milliamperes, or 2.62 times the rheobase; at 3.8 seconds, 1.1 milliamperes, or 2.75 times the rheobase (Fig. 1). At no time was the rheobase current adequate to stimulate; yet with a current of long duration, 8.8 seconds, an increase of only 2.87 times the rheobase was an effective stimulus.

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In earlier years the impetus for development of new wave forms of stimulation was the desire to imitate the normal contraction of a muscle and to avoid the abrupt movement produced by sudden closure of a current, whether faradic or galvanic (Bergonie). In 1907 Bordet described an apparatus for the production of a galvanic wave current lasting as long as 2.5 seconds. With regard to diagnosis, he noticed that when a muscle is degenerated the time necessary to reach a current adequate for stimulation is long as compared with that necessary for normal muscle, with which the liminal current must be reached more quickly. For similar reasons, Laquerriere designed a new apparatus on the basis of the work of Bergonie. In 1912 Becker described an apparatus called a myomotor, which delivered saw tooth waves. In 1931 Delherm and Laquerriere described an apparatus which delivered alternating currents of long duration and unidirectional galvanic wave forms. The currents described by Bordet, Laquerriere, and Delherm, Duhem designated as currents of long period, to distinguish them from currents described by d'Arsonval in 1891 and by Lapicque, who, without knowledge of the work of d'Arsonval, published his results in 1915.

Whereas the currents designated as those of long period may last several seconds, those designated as progressive currents by Delherm last only a fraction of a second. From the standpoint of their contribution to diagnosis, it is said of both types that a degenerated muscle will respond to the condition in which a liminal current is reached more slowly, whereas with the normal muscle this amperage must be reached more quickly.

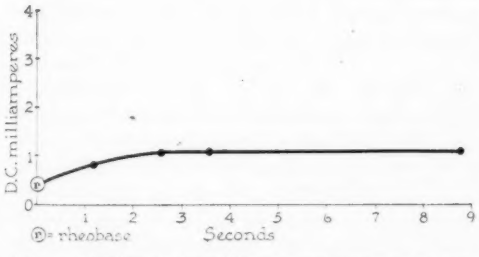

Fig. 1. Median of the milliamperages necessary to produce an adequate stimulus with progressive currents of various durations in 25 normal animals.

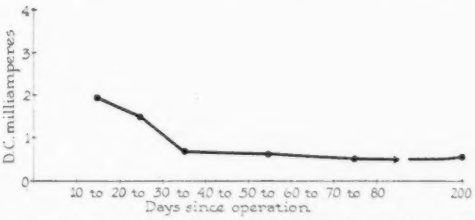

Fig. 2. Average milliamperage necessary to produce adequate stimulus of the gastrocnemius muscle with a progressive current of 3.8 seconds' duration at various days following denervation in 15 cats.

Although many articles in the literature are concerned with progressive currents of long period (more than 2 seconds), the clinical material from which data have been obtained is small. No accurate measurements of time and current are described, and no experimental work is recorded.

It is necessary, we believe, better to define a progressive current. We take such a current to be one which increases with time. The kind of progressive current is determined by its wave form; for example, whether linear, exponential, or sinusoidal. The progressive current used in our former experiments was a linearly increasing one, consisting of the ascending limb of a unidirectional galvanic wave of isosceles triangle type. The decision to use a current wave of this type in preference to a saw tooth wave was based on several considerations. In the first place, one is able to observe a contraction at the peak of the wave. Also, one is able to obtain simultaneous readings of the voltage and strength of current at the instant of the contraction. In addition, one is spared the confusion resulting from unwanted break contractions, which are likely to occur with the saw tooth wave.

As the result of former experiments we showed that in the cat, within a few days after denervation, the amount of current necessary to excite the muscle by progressive currents of long duration was usually somewhat higher than the amount required by the normal muscle. It began to diminish after about 20 days, and between 30 and 40 days it was less than normal and remained so as long as the animals were studied.

It was seen that as long as 203 days after denervation, the rheobasic current being 0.18

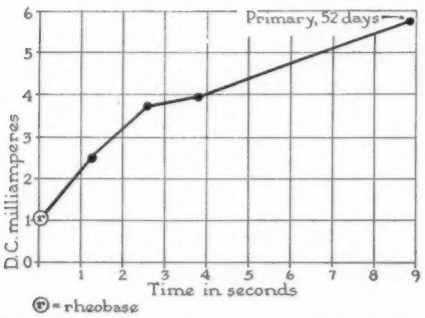

Fig. 3. Milliamperage necessary to produce adequate stimulus of the gastrocnemius muscle of a cat, 52 days after primary suture and 4 days after a response characteristic for denervated muscle has been found.

milliampere, contraction occurred at 8.8 seconds with 0.27 milliampere (Fig. 2).

In contrast to the period of denervation, at times before, and sometimes coincident with evidence of motor return, the amount of current necessary to produce excitation must be increased considerably above the rheobase when the current is allowed progressively to increase for long periods. Thus, in Figure 3, 4 days prior to the recorded examination made 52 days after primary suture the muscle reacted as a denervated one. On the 52d day the rheobase was 1.15 milliamperes; at 1.2 seconds contraction occurred with 2.5 milliamperes; at 2.6 seconds with 3.75 milliamperes; at 3.8 seconds with 4 milliamperes; and at 8.8 seconds with 5.75 milliamperes. As regeneration progresses, the amount of current necessary for excitation becomes even greater, and a normal pattern is not reached even when fairly good motor recovery has taken place (Fig. 3).

Soon after we had begun to examine muscles supplied by injured peripheral nerves in man, it was found that the use of absolute values of the threshold amperage for progressive currents of long duration to indicate denervation and regeneration might lead to misinterpretation in some cases. The reason for this is found in the fact that when the rheobase is high, the threshold amperage for progressive currents must be higher; therefore, when as the consequence of edema or other changes in the tissues, the rheobase or threshold current for instantaneous stimulus is high, the threshold amperage for progressive currents must be higher; therefore, when as the consequence of edema or other changes in the tissues, the rheobase or threshold current for instantaneous stimulus is high, the threshold amperage for progressive currents must be higher; therefore, when as the consequence of edema or other changes in the tissues, the rheobase or threshold current for instantaneous stimulus is high, the threshold current for progressive current is of long duration must be still higher. As a result, in some cases, when a muscle is denervated, the absolute value of the threshold amperage for progressive currents of long duration may be high, in others, low.

From data described in preceding paragraphs it may be seen that the ratio between the rheobase and the threshold amperage of a progressive current lasting 8.8 seconds was 2.87 in the normal muscle of a cat; 1.5 for a denervated one; and 7.7 for the recovering muscle, 52 days after suture. When, therefore, one finds a muscle with a high rheobase, it is necessary to determine the ratio between the rheobase and the threshold current for stimuli by progressive currents of long duration. This ratio may be called the ratio for progressive currents, to distinguish it from the tetanus ratio for instantaneous current stimulus.

The ratio for both cathodal and anodal stimuli should be obtained since, as will be seen, the approach toward unity of the polar ratios for progressive currents is characteristic of the state of denervation of a muscle.

The evolution of the changes in this ratio, as well as the threshold current, as related to the time following section and suture of the sciatic nerve in the cat, is constant and characteristic. These changes may be divided into four periods. The first, during the very early period of degeneration, occupying about 14 days; the second during the remaining period of degeneration until the period of complete denervation had occurred, from the 31st to the 49th day; the third, the period of denervation, and the fourth the period of regeneration, beginning from the 49th to the 66th day.

During the first 14 days a number of changes occur, the significance of which we do not at this time know. They consist of two phenomena: first, a very rapid fatigability to progressive currents, and a failure to contract when the current is increasing, but a contraction when after a current has reached its peak, it

approaches zero. Exclusive of this very early change, the responses during the period of degeneration and regeneration have a remarkable similarity. During degeneration there is a rapid increase in threshold current both for anodal and cathodal stimuli by progressive currents of long duration, reaching a peak at variable times, usually from the 17th to the 23rd day; at the same time there is an increase of the ratio of progressive current both for anodal and cathodal stimuli, but usually in contrast to the period of degeneration, the increase in the ratio is much greater than the increase in threshold current. Then both the threshold current and ratio continue to diminish until the period of complete denervation occurs. At this time the threshold current is at a minimum both for anodal and cathodal stimuli, and the ratio often is at unity or a little more both in the case of anodal and cathodal stimuli. When regeneration occurs there is a relatively sudden increase in threshold amperage for both anodal and cathodal stimuli and also a marked increase in the ratio both in the case of anodal and cathodal stimuli (Fig. 4). During the very early stage of regeneration, the same peculiar reactions as were seen during very early degeneration are at times noted, particularly failure to contract when the current is increasing, and response when, after having reached its peak, the current has returned to almost zero.

The state of denervation is readily demonstrable by the approach to unity of the ratio and minimal threshold current as well as the approach to unity of the polar ratio. If one does not take into account the time which has elapsed since the date of injury so that an opinion may be derived as to whether the state of denervation should be present were the nerve severed or completely injured, then from the data of a single examination, there might be some difficulty in differentiating the increase of threshold amperage and ratio found during degeneration from that found during regeneration. Usually, although the ratio is high in both, the threshold amperage is much lower during degeneration than regeneration. Thus it may be said that when the threshold amperage is only moderately high and the ratio quite high, we are dealing

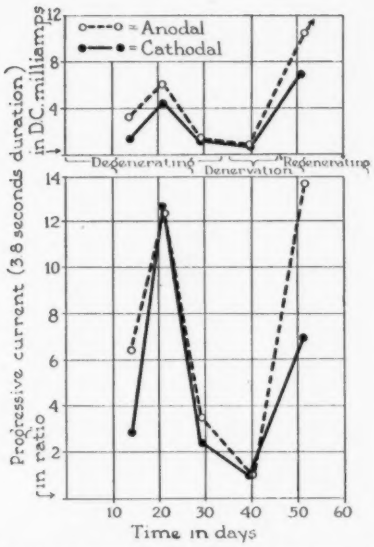

Fig. 4. Milliamperage necessary to produce adequate stimulus of the gastrocnemius muscle with a progressive current of 3.8 seconds' duration and the progressive current ratio at various days after primary suture of the sciatic nerve of a cat.

with the changes of degeneration. When both threshold amperage and ratio are high, we are dealing with regeneration.

Although we have found this to be true in our experimental work on the cat, we have found an occasional exception in man, when the threshold amperage as well as the ratio was high, and even higher during degeneration than regeneration. However, if sufficient time has elapsed for complete denervation to have taken place, then a high threshold amperage and high ratio indicates recovery. If at one examination a liminal threshold amperage and a ratio approaching unity and an approach to unity of the polar ratio are found and at a subsequent examination a high threshold amperage and high ratio are found, recovery is indicated.

CLINICAL APPLICATION

Although unequivocal evidence for the state of denervation and recovery in experimental lesions of the sciatic nerve in the cat has been adduced by data obtained from stimuli by progressive currents of long duration, the

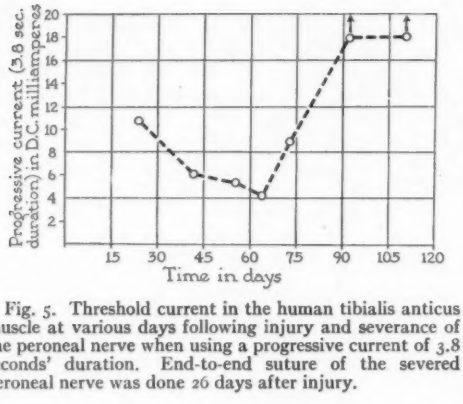

Fig. 5. Threshold current in the human tibialis anticus muscle at various days following injury and severance of the peroneal nerve when using a progressive current of 3.8 seconds' duration. End-to-end suture of the severed peroneal nerve was done 26 days after injury.

validity of this method of diagnosis must be tested by its application to injuries of the peripheral nerves in man.

We have examined over 50 cases with lesions of various peripheral nerves; about half of these were civilians and the others wounded soldiers examined at the Percy Jones General Hospital at Battle Creek, Michigan.

The evolution of the changes in threshold amperage and ratio for progressive current stimuli in time, after injury to a peripheral nerve injury in man is the exact counterpart of that in the cat.

Exclusive of the very early changes observed in the cat, in man after the 14th day following severe injury, there is a rapid increase in threshold amperage for anodal and cathodal stimuli by progressive currents of both 1 and 4 seconds' duration. This is succeeded by a progressive diminution in threshold amperage until the period of denervation is reached, when it is at its minimum and the polar ratio approaches unity. Then when recovery occurs, there is again a rise in threshold amperage usually of a much higher order than was the case during the period of degeneration. This may be illustrated by the chart plotting the measurements obtained in a case of peroneal nerve severed by a knife blade, at varying days following injury and suture (Fig. 5).

In addition, there is a parallel change in the ratio, derived by dividing the rheobase of anodal and of cathodal stimuli, respectively, into their threshold current. At first there is a rise in the ratio for stimuli of both 1 and 3.8 or 4 seconds' duration, then a diminution until at the period of denervation the ratio approaches, or is at unity and the polar ratio also approaches unity. Then, when recovery occurs, the ratio increases, usually to a degree as high, often higher, than during the period of degeneration. This may be illustrated by a graph plotting the ratio for stimuli of 1 and 3.8 or 4 seconds' duration, in a case of Bell's palsy, beginning 27 days after its onset (Fig. 6).

During the period of denervation a unity is approached or exists for the threshold amperage and the ratio for stimuli of 1 or 4 seconds' duration. On the other hand, during degeneration and regeneration the threshold amperages and ratio for stimuli of 1 and 4 seconds' duration, respectively, differ; those for the stimulus lasting 4 seconds being higher. This may be seen in Figure 7.

When it is possible to examine a patient who has sustained an injury to a peripheral nerve at frequent intervals throughout the whole period of time from that of injury to that of recovery, the validity of a method could quickly be determined. Unfortunately, we have been able to do this only in a few cases among the civilian population.

More frequently we had the opportunity to examine patients but once or twice at some periods of time following injury or operation. This was particularly true of the cases of wounded soldiers. Certain other standards, however, can be established for the validity of this method in such cases. In the majority of cases we did not have the opportunity of examining the patient until a time had elapsed

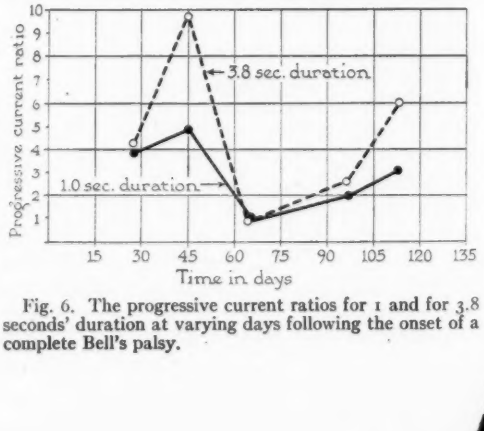

Fig. 6. The progressive current ratios for 1 and for 3.8 seconds' duration at varying days following the onset of a complete Bell's palsy.

which either resulted in a state of denervation or a state of recovery from a severe lesion.

When the characteristics of a state of denervation in a muscle had been found, the validity of such a diagnosis could be assessed by the following means. First, that at operation preceding the examination by a number of days insufficient for regeneration to occur, the nerve ends were found to be severed. Second, that subsequent operation revealed a severed nerve. Third, when a state of denervation was found in a patient in whom operation was not performed, spontaneous recovery later occurred at a time compatible with regeneration and was made evident by the characteristic changes in threshold amperage and ratio, or later, recovery of motion or sensation or both. Fourth, when in some of the muscles supplied by an injured nerve, characteristics of recovery are found by examination with progressive currents of long duration and in another, or others, characteristics of denervation, these muscles later, at a time compatible with regeneration, show characteristics of recovery of muscles, as found by examination with progressive currents or recovery of motion or sensation, or both. Fifth, the characteristics of regeneration follow those of denervation at a time when regeneration could have occurred.

When the characteristics of a state of regeneration or recovery had been found, the validity of such a diagnosis could be assessed by the following means. First, that at operation preceding the examination, the nerve was found not to be severed or completely compressed. Second, that at subsequent operation the nerve was found not to be severed or completely compressed. Third, that motor or sensory recovery ensued. Fourth, that motor or sensory recovery was present at the time of examination. Fifth, when some of the muscles supplied by a nerve showed the characteristics of recovery, later recovery of motion and sensation occurred.

RESULTS OF PERIPHERAL NERVE INJURIES IN MAN

In 36 patients, at one time or another, in the course of recovery after a peripheral nerve lesion, examination by progressive currents of long duration showed the characteristics of a

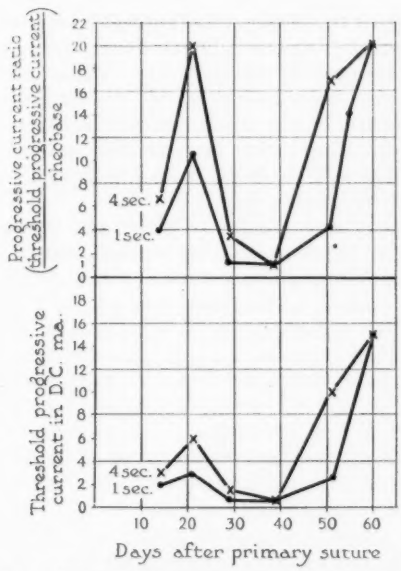

Fig. 7. Threshold progressive current and ratios of 1 and 4 seconds' duration in the gastrocnemius muscle at varying days following primary suture of the sciatic nerve in the cat.

recovering nerve-muscle complex. The confirmation of the validity of this electrical sign consisted, in one case, of an exploration a short time before examination which revealed no severance of the nerve; in another, exploration soon after examination showed no discontinuity of the nerve. In 24 there was subsequent clinical evidence of recovery of motion or sensation, or both. In 8, clinical signs of recovery of motor or sensory function were present at the time of electrical examination. In 2, the validity of the characteristics of recovery consisted of their appearance after the electrical signs of denervation had been present and a period of time compatible with recovery ensued. This progression from the electrical signs of denervation to those of regeneration were also found in 7 other patients in whom the validity of the electrical signs of regeneration were confirmed by the fact that at an exploratory operation performed a few days before the examination, the nerves were found severed in 6 cases. In 1 case, a hypoglossal facial anastomosis had been performed before the examination. In 6, later recovery

of motor or sensory function followed the appearance of electrical signs of recovery, at a time compatible with recovery. Three of these had also been confirmed by the findings at operation. In 2, there occurred recovery of motion or sensation or electrical signs of regeneration at a later date, which was compatible with recovery.

There were 4 cases in which the rheobase was so high, in 1, 40 milliamperes, that examination by progressive current was impossible, both because of insufficient output of current and, if available, such currents would be unbearable. That such a high rheobase is a sign of recovery was found from the fact that later clinical evidence of recovery of motion or sensation or both was found in all cases, and in 1, electrical examination conducted 82 days later revealed the characteristics of recovery and motor recovery had begun.

In 4 cases, electrical signs of recovery were found, but at clinical examination, 280, 130, 97, and 90 days, respectively, after injury, no motor or sensory recovery was demonstrated. However, it is quite probable that such recovery will take place. In 1 case, electrical signs of recovery were shown to be present only 36 days after suture of a peroneal nerve; although this is quite early, nevertheless, we felt that it is quite possible that the nerve is recovering.

In only 2 cases was the method brought into question. In both, the deep branch of the radial nerve was injured. In 1, the electrical examination was performed 140 days after injury and again 14 days after operation, which revealed that the nerve was severed. In the other, the electrical examination was conducted 12 days after operation which revealed a severance of the deep branch of the radial nerve. The operation was performed 95 days after injury. Only one muscle had been examined in each of these cases. Here we feel it is quite possible that some new fibers had found their way to the distal segment.

Of 52 patients examined, when electrical signs of recovery occurred, the later course confirmed their validity in all but 7 cases; in 5, the time which elapsed from the date of suture or injury may well be too short for motor or sensory recovery. In 2, only, was there an equivocal result. In all of the instances when the electrical signs of denervation were found, there was a confirmation of the validity of this electrical sign.

DISCUSSION

The indication for the development of methods of electrodiagnosis other than by examination by stimuli of galvanic and faradic current as described by Erb, is found in the failure of such methods, as ordinarily performed, to give accurate evidence of the states of degeneration, denervation, and regeneration. Some of this inaccuracy is the result of imperfect knowledge of the difference in the responses during denervation and regeneration. Some is the result of incorrect views which have been passed down in text books and literature and part due to limitations of such methods.

The state of complete denervation of a muscle can with assurance be determined by such methods, both by the very small threshold amperage or rheobase and the approach toward or to unity of anodal and cathodal closing stimuli or unity of polar ratio. The 2 other states, degeneration and regeneration, are then recognizable by the absence of the characteristics described. However, it would be difficult to differentiate the degenerating from the regenerating state. Although the existence of response to faradic current, 14 or more days after a lesion, indicates a spontaneously recoverable lesion, this method is of little value in war wounds. Such lesions recover in a short period of time, and by the time a wounded man would have reached a hospital suitable for nerve surgery, recovery of motion or sensation, or both, would have occurred. On the other hand, in a spontaneously recovering, but severely injured nerve, other clinical signs of recovery usually antedate the response to faradic current.

Although our former work on stimulation by progressive currents of long duration indicated clearly that the relatively rapid increase of threshold amperage was an accurate indication of recovery, further work upon human material showed that this was not in itself a safe indication. The reason for this was found in the fact that in some cases, because of edema and other subcutaneous changes, a high

threshold amperage may be present only because the rheobase or threshold amperage for instantaneous stimuli of "infinite" duration was also high. It was therefore concluded that determination of the ratio for progressive currents of long duration was a necessary part of the examination. This is the ratio between the threshold amperage of a progressive current of any given duration and the rheobase, both for anodal and cathodal stimuli.

We have shown that the characteristics of response to progressive currents during degeneration consist of (1) some unexplained peculiar responses very early during degeneration, usually within the first 14 days, consisting of contraction when the current has reached zero from a peak; (2) a subsequent early rise in threshold amperage and in ratio both for anodal and cathodal stimuli; (3) a fall in both, as the state of denervation is approached, during all this time there is a disunity between anodal and cathodal stimuli. During denervation the characteristics of changes occurring consist of a minimal threshold amperage, an approach toward or to unity of anodal and cathodal stimuli and a unity of the ratio for progressive currents, both in the case for anodal and cathodal stimuli. When regeneration occurs, during a very short time the characteristic changes are fleeting responses, only when the current has reached zero from a peak, then a sudden increase in threshold amperage for progressive currents, usually much higher than in the degenerating state, a very high ratio and a disunity between anodal and cathodal stimuli.

In interpreting the results of examination by progressive currents of long duration, it is found that the characteristics of the state of denervation are unique for that state. Both during some time of degeneration and during regeneration, a high threshold amperage for progressive currents and ratio is present. However, a high ratio and only a moderately high threshold amperage are found during the state of degeneration and a very high ratio and also threshold amperage during regeneration.

The time which has elapsed from the date of injury or surgery must also be taken into consideration. When a sufficient time after injury has elapsed to permit the development of the state of denervation, and the characteristics of denervation not found, the nerve is spontaneously recovering and should not be operated upon. If after a suture of severed ends of nerves characteristic of the denervated state are not found, one may be certain recovery is taking place. When a sufficient time has elapsed after injury to a nerve to have permitted regeneration and the characteristics of denervation are found, the nerve must be operated upon.

Although the characteristics of the regenerating state indicate that some nerve fibers have regenerated and reached the muscle being examined, this does not predicate complete recovery of other muscles supplied by the nerve involved. More accurately, to predict the completeness of recovery, all of the principle muscles supplied by such a nerve must be examined. At times proximal muscles may show the characteristics of regeneration, for example, the flexor sublimis digitorum and flexor profundus digitorum and the flexor carpi radialis in a median nerve lesion and the abductor brevis pollicis and opponens pollicis show the characteristics of denervation. In such a case, the later appearance of the characteristics of regeneration in the latter muscles would lead to a good prognosis.

For the most part, a high rheobase at a time when, if a nerve would have degenerated completely, were it severely injured or severed, indicates recovery. When such a rheobase is so high that examination by progressive current is impractical either because sufficient amperage would not be available or because of the painfulness of the very high order of current necessary, further examination is needed. This should consist of determining whether the anodal and cathodal closing stimuli are at or near unity and whether the ratio between the tetanus produced by instantaneous stimulus by strong currents of "infinite duration" or square waves and the rheobase also approaches or is at unity. When these characteristics are found, despite the high order of the rheobase, the muscle is in a state of denervation. The necessity for this additional examination, however, rarely occurs, and when it does, ordinarily characteristics of regeneration will be found.

These electrical signs of recovery have been found to precede clinical evidence of motor or sensory recovery for variable times. In some instances, the interval was quite long, in one, it was 150 days.

CONCLUSIONS

1. The characteristics of responses to progressive currents of long duration during degeneration, denervation, and regeneration are described.

2. The usefulness of the computation of a ratio for currents of long duration is pointed out.

3. The characteristics of the state of denervation as described are unique for that condition and consist of a minimal threshold amperage for contraction and unity of ratio for stimuli by progressive currents of long duration.

4. A very high ratio or a very high threshold amperage are indicative of regeneration.

5. A high ratio and only a moderately high threshold amperage are characteristic of the degenerating state.

6. The validity of this method of examination for the diagnosis and prognosis of peripheral nerve lesions in man was established by the examination of 52 patients suffering from peripheral nerve lesions. In only 2 cases was there any question of its accuracy, and for these 2 a possible explanation is made.

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THE EFFECT OF COTTON AND CATGUT IN HERNIAL REPAIR ON POSTOPERATIVE TEMPERATURE AND PAIN

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AN Army Hospital offers an unusual opportunity to study wound healing in a standard group of young men who are well fed, well muscled, and otherwise in good health. Therefore, an analysis was made of the inguinal hernia operations done with either catgut or cotton sutures at the A.A.F. Regional Hospital, Truax Field. This study was done in order to determine whether any completely objective, measurable evidence could be found to support the use of one type of suture material over the other.

The clinical impression, that wounds which are closed with nonabsorbable sutures heal more readily than do those closed with catgut, is in accordance with the writings of Kocher, Halsted, Whipple, Shambaugh, and Howes and Harvey; also, the clinical impression that cotton excites even less reaction in a wound than does silk is in agreement with the work of Mead and Ochsner.

Direct, completely objective, unbiased measurement of the degree of postoperative reaction excited by certain suture materials in groups of human patients is not practical to obtain. Indirect methods are of value if applied to a sufficiently large, well standardized group of cases. These methods have been used in cases in which wounds have been closed with catgut and cotton sutures by measuring, (1) the temperature reaction, and (2) the narcotics and sedatives required for relief of postoperative pain.

CASES ANALYZED

Groups of herniorrhaphies, standardized except for the suture material, were analyzed (Table I). Approximately half of the cases were repaired with cotton and half with catgut. No recurrent hernias were included in the series. The differences in average age, height, and weight of patients represented in the groups were not significant (Table III). The operations were performed by a number of surgeons, including residents in training. No one surgeon did enough of the operations, in any group, to affect the statistics appreciably by his skill or lack of skill. The average operating time, in the cotton and catgut groups, was not significantly different (Table III). All operations were performed under spinal anesthesia with 8 exceptions. In 1, general anesthesia supplemented the spinal; in 7, general anesthesia was used throughout. The postoperative reactions in these 8 cases are within the normal distribution for the groups and do not affect the final averages.

Following operation, these patients were returned to the various surgical wards without distinction as to the type of suture material used. Because these soldiers were young and in good general health, it was possible to employ routine orders in all cases during the immediate postoperative period. The nurses had no knowledge of the type of suture material used, so the drugs were administered as required by the patient's own subjective reactions. Since the cases were analyzed over a considerable period of time, many different nurses cared for these patients. Therefore, if any nurse had personal prejudice as to the giving of drugs postoperatively, her feeling would not appreciably affect the results in the series. The postoperative temperatures of patients were factual, affected only by the patient's physical status. All patients developing any type of postoperative complication were excluded from the final analysis.

In this study, 163 unilateral and 50 bilateral inguinal herniorrhaphies were reviewed (Table I). Eighty-three of the unilateral hernias were repaired with cotton. Five of these cases were excluded from the final analysis due to postoperative complications, which were: pulmonary, 1 case; upper respiratory infection, 3 cases; scarlet fever with secondary deep stitch abscess, 1 case. Eighty unilateral hernias were repaired with catgut. Eleven of these cases were excluded due to postoperative complications, which were: pulmonary, 3 cases; stitch abscesses, 3 cases; wound infection, 2 cases; upper respiratory infection, 1 case; scarlet fever, 1 case; hematoma in the wound, 1 case. Twenty-five bilateral hernias were repaired with cotton. Seven cases were excluded due to postoperative complications, as follows: pulmonary, 4 cases; hematoma in wound, 2 cases; stitch abscess, 1 case. Twenty-five bilateral hernias

From the Surgical Service, A.A.F. Regional Hospital, Truax Field, Madison, Wisconsin.

TABLE I.—HERNIORRHAPHIES ANALYZED

	Cotton		Catgut	
	Unilateral	Bilateral	Unilateral	Bilateral
Number of cases	83	25	80	25
Cases eliminated (postoperative complications)	5	7	11	5
Net total	78	18	69	20
Cord transplanted subcutaneous	5	9	17	10
Cord transplanted (Bassini)	20	5	12	3
Cord not transplanted	53	4	40	7

were repaired with catgut. Five were excluded due to postoperative complications, which were: pulmonary, 2 cases; upper respiratory infection, 1 case; incision into bladder at operation, 1 case; mild wound infection, 1 case.

After all cases with postoperative complications were excluded, there remained for analysis 78 unilateral and 18 bilateral hernias repaired with cotton; and 69 unilateral and 20 bilateral hernias repaired with catgut. Several different types of repair were done. The type of hernia repair was not found to have a statistically significant effect on the final results in this study.

There was no significant difference in the average age, weight, and height of the patients having cotton and catgut unilateral herniorrhaphies. Likewise, the difference in operating time was not striking. The same was true for the bilateral herniorrhaphy groups (Table II).

TABLE III.—UNILATERAL HERNIORRHAPHIES STATISTICAL ANALYSIS OF POSTOPERATIVE TEMPERATURES

Postoperative days	Average temperature		Difference in means (x)	Difference in standard error	$\frac{x}{\sigma}$	Remarks*
	Cotton	Catgut				
Day of operation	98.7	99.0	0.3	0.112	3.7	S†
1	99.4	100.0	0.6	0.115	5.2	S
2	99.0	99.8	0.8	0.104	7.7	S
3	98.7	99.1	0.4	0.086	4.6	S
4	98.6	98.8	0.2	0.059	3.3	S
5	98.6	98.8	0.2	0.041	4.9	S
6	98.6	98.6	0.0			

*For an explanation of statistics, see Croxton, F. E. and Cowden, D. J. Applied General Statistics. New York: Prentice Hall, Inc., 1939.
†S=Significant. The "0.01 level of significance" has been chosen. At this level, $\frac{x}{\sigma}=2.58$.

TABLE II.—ANALYSIS OF COMMON FACTORS

Hernia	Suture	Average age	Average weight	Average height	Average operating time	Number of cases
Unilateral	Cotton	25.4	156.6	5′ 9.5″	44.1	78
	Catgut	23.6	159.2	5′ 9.3″	45.2	69
Bilateral	Cotton	31.5	165.0	5′ 9.1″	86.9	18
	Catgut	27.7	157.2	5′ 8.7″	72.3	20

POSTOPERATIVE TEMPERATURES

Postoperative temperature curves were determined for each of four groups in order to compare the unilateral cotton to the unilateral catgut herniorrhaphies, and the bilateral cotton to the bilateral catgut cases. These curves were determined by taking the highest daily postoperative temperature of each patient in each group until normal temperatures persisted. The average daily postoperative temperature was then calculated for the group. As expected, the average temperatures of the unilateral groups were lower than those of the bilateral groups.

The difference between the temperature curve of the unilateral cotton herniorrhaphies and the unilateral catgut herniorrhaphies was striking (Fig. 1). The average temperature on the first postoperative day was 99.4 degrees F. for cotton, as compared to 100.0 degrees F. for catgut. Furthermore, a normal average temperature was attained, in the cotton cases, on the fourth postoperative day, compared to the sixth postoperative day for

TABLE IV.—BILATERAL HERNIORRHAPHIES STATISTICAL ANALYSIS OF POSTOPERATIVE TEMPERATURES

Postoperative days	Average temperature		Difference in means (x)	t*	n (N-1)	t at 0.01 Level of probability	Remarks
	Cotton	Catgut					
Day of operation	98.8	98.85	0.05		18	2.88	N.S.†
1	99.9	100.4	0.5	2.6	18	2.88	P.S.‡
2	99.7	100.6	0.9	3.0	18	2.88	S.↓
3	98.9	99.6	0.7	2.8	18	2.88	S.
4	98.7	99.9	1.2	5.7	18	2.88	S.
5	98.6	99.1	0.5	3.1	18	2.88	S.
6	98.6	98.8	0.2	3.3	18	2.88	S.
7	98.6	98.6	0.0		18	2.88	

*For an explanation of the application of Fisher's "t" test, see Applied General Statistics by Croxton and Cowden, pp. 325-331. New York: Prentice Hall, Inc., 1939.
†Not significant.
‡Probably significant.
↓Significant.

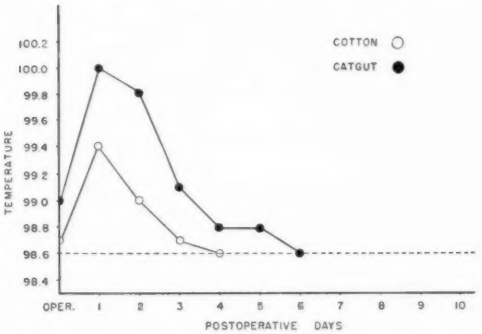

Fig. 1. Graph illustrating the difference in postoperative temperatures of patients having unilateral herniorrhaphies with cotton or catgut suture material.

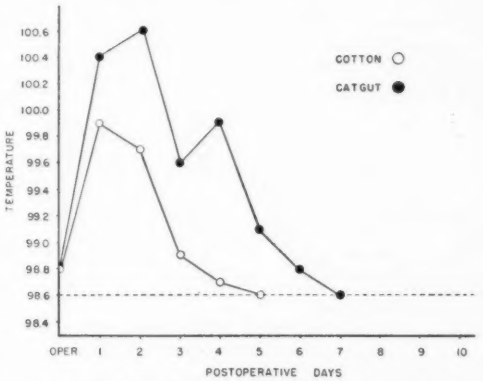

Fig. 2. Graph illustrating the difference in postoperative temperatures of patients having bilateral herniorrhaphies with cotton or catgut suture material.

the catgut cases. These figures are of statistical significance (Table III).

Temperature curves, which were similar but of greater magnitude, were found in the bilateral herniorrhaphy groups (Fig. 2). The average temperature for the first postoperative day was 99.9 degrees F. for cotton, as compared to 100.4 degrees F. for catgut; second postoperative day 99.7 degrees F. for cotton, 100.6 degrees F. for catgut; third day 98.9 degrees F. for cotton, 99.6 degrees F. for catgut. Furthermore, a normal average temperature was attained in the cotton cases on the fifth postoperative day, as compared to the seventh postoperative day in the catgut cases. The statistical significance of these figures is shown in Table IV.

NARCOTICS AND SEDATIVES

The amount of narcotics and sedatives given postoperatively was now determined for the four groups. This was done in order to compare the subjective discomfort of the unilateral cotton to the unilateral catgut herniorrhaphies, and the bilateral cotton to the bilateral catgut herniorrhaphies. The average number of doses of each drug per patient was determined (Fig. 3). Patients with unilateral hernias, repaired with catgut, required nearly twice as much narcotic as those repaired with cotton. It seemed evident, therefore, that the postoperative course following catgut herniorrhaphies was more painful than that following cotton herniorrhaphies. In the place of narcotics, the patients in the cotton group used nearly twice as much sedation as did the patients in the catgut group. This fact was evidence of restlessness rather than pain. The statistical significance of these figures is outlined in Table V.

TABLE V.—UNILATERAL HERNIORRHAPHIES STATISTICAL ANALYSIS OF NARCOTICS AND SEDATIVES

Narcotics and sedatives	Average number of doses per patient		Difference in means (x)	Difference in standard error	$\frac{x}{\sigma}$	Remarks*
	Cotton	Catgut				
Codeine	0.224	0.460	0.236	0.161	1.5	N.S.†
Morphine	1.84	3.24	1.40	0.312	4.5	S.‡
Barbiturate	2.32	1.32	1.00	0.288	3.5	S.

*The "0.01 level of significance" has been chosen. At this level $\frac{x}{\sigma} = 2.58$.

For an explanation of statistics see Croxton and Cowden Applied General Statistics. New York: Prentice Hall, Inc., 1939.
†Not significant.
‡Significant.

TABLE VI.—BILATERAL HERNIORRHAPHIES STATISTICAL ANALYSIS OF NARCOTICS AND SEDATIVES

Narcotics and sedatives	Average number of doses per patient		Difference in means (x)	t*	n (N-1)	t at 0.01 level	Remarks
	Cotton	Catgut					
Codeine	0.055	0.487	0.432	1.4	18	2.88	N.S.†
Morphine	3.07	5.82	2.75	2.4	18	2.88	P.S.‡
Barbiturate	4.17	1.57	2.60	5.9	18	2.88	S.↓

*For an explanation of Fisher's "t" test, see Applied General Statistics by Croxton & Cowden, pp. 325–331. New York: Prentice Hall, Inc., 1939.
†N.S. Not significant.
‡P.S. Probably significant.
↓S. Significant.

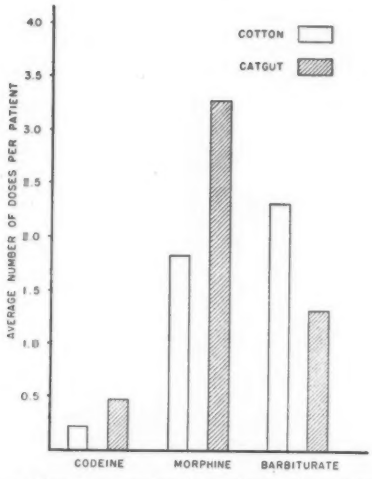

Fig. 3. Graph comparing doses of narcotics and sedatives given postoperatively to patients with unilateral herniorrhaphies sutured with cotton or catgut.

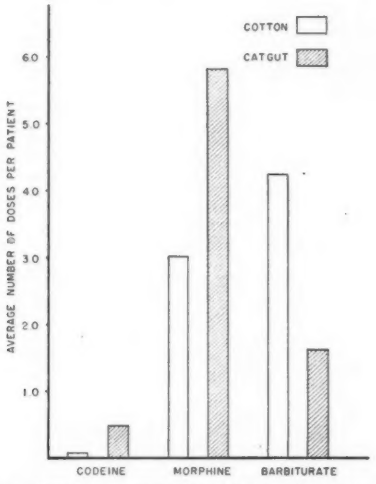

Fig. 4. Graph comparing doses of narcotics and sedatives given postoperatively to patients with bilateral herniorrhaphies sutured with cotton or catgut.

In the bilateral herniorrhaphy groups the findings closely paralleled those in the unilateral groups. As expected, there was a greater but proportionate increase in the drugs needed (Fig. 4). The statistical significance of these figures is outlined in Table VI.

EVALUATION OF STUDY

This study of the immediate postoperative convalescence of uncomplicated herniorrhaphies showed that the patients with cotton repaired wounds had less general reaction than patients with catgut repaired wounds. This fact was evidenced by a lower daily temperature and a quicker return to normal by the cotton groups. Postoperative temperature is not due to suture material alone. In this study, however, other factors which might influence postoperative temperature were controlled in the compared groups. The only important difference between the groups was the suture material used. There is no way to determine how much of the postoperative temperature in the cotton repaired groups was due to suture material and how much was due to other factors. It is reasonable to deduce, however, that the statistically significant difference of postoperative temperature in the catgut groups compared to the cotton groups was due to the difference in suture materials. As has been shown, this difference is definite and significant. These data substantiate the laboratory and clinical findings that wounds sutured with cotton show less postoperative induration and faster resolution of this induration than wounds sutured with catgut.

The study also indicated that patients with cotton repaired wounds had a more comfortable postoperative convalescence, as evidenced by the fact that patients with catgut repaired wounds required more narcotics. In contrast, the patients with cotton repaired wounds were able to rest with a sedative instead of a narcotic. These findings are in keeping with the impression that the more marked induration in the catgut repaired wounds was associated with more tenderness in the wound area and increased subjective discomfort on the part of the individual patient.

By the time this series of cases had been completed, the surgeons of this general surgical service were in unanimous agreement that wounds repaired with cotton showed less postoperative induration and seemed less painful than wounds repaired with catgut. For these reasons the catgut repair of hernia has been discarded on this surgical service.

SUMMARY

In this study 163 unilateral and 50 bilateral inguinal herniorrhaphies, in otherwise healthy young males, were reviewed to determine the advantage of either catgut or cotton suture material. All cases with postoperative complications were excluded from the final analysis. There remained 78 unilateral and 18 bilateral herniorrhaphies repaired with cotton, and 69 unilateral and 20 bilateral herniorrhaphies repaired with catgut.

A comparison of the postoperative temperatures revealed that patients with unilateral or bilateral herniorrhaphies sutured with cotton averaged a lower daily postoperative temperature which returned more quickly to normal than patients undergoing similar procedures in which catgut sutures were used.

A comparison of the postoperative narcotics and sedatives administered revealed that the patients with unilateral and bilateral inguinal herniorrhaphies sutured with cotton required less narcotics than patients undergoing a similar procedure in which catgut sutures were used. The patients with wounds sutured with cotton required more sedatives.

The presented data support the clinical impression that patients with wounds sutured with cotton material showed less postoperative wound reaction and were more comfortable than patients whose wounds were sutured with catgut.

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PARA-ARTICULAR CALCIFICATION (PELLEGRINI-STIEDA) IN AFFECTIONS OF THE KNEE

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THE existence of anomalous calcifications medial to the lower end of the femur has been known for a number of years (3, 4). Though this condition was originally considered to be a rarity, recent reports indicate that it is not uncommon. The nature of the mass, its origin, its exact location, and the proper manner of treatment have all been subject to varying opinions.

Opportunity has been presented to us to study carefully a rather large number of patients with such calcific deposits. Within 6 months 20 men have been sent to us for examination and treatment for this condition. It has been possible to make careful clinical and roentgenologic studies of these patients. In addition, we were able to obtain 1 specimen at operation, and laboratory studies of this specimen have been made. Finally, dissection of the pertinent area in 9 cadavers in 1 "fresh" knee at autopsy, gave us the opportunity to establish some interesting facts relative to the pathologic anatomy.

PATHOLOGIC ANATOMY AND PATHOGENESIS

There has been considerable controversy as to which tissues are involved in the formation of the calcified mass. The tibial collateral ligament, the tendon of the adductor magnus muscle, bursae, the periosteum, and the bone itself have all been considered (1). A careful study of the roentgenograms has been helpful in locating the calcification.

Roentgenographic examination revealed these calcified masses to be situated in the soft tissues on the medial aspect of the knee, directly overlying the adductor tubercle (Fig. 1). In a few instances they seemed to be continuous with the bone proper. In these cases if we changed the position of the knee slightly and took new roentgenograms, we could demonstrate that a radiolucent layer existed between the condyle and the calcareous mass (Fig. 2). This translucent layer is thin, usually less than a millimeter in width. The calcification is difficult to see on a lateral view of the knee joint, indicating that it is not very dense or thick. The level at which it is noted is that of the adductor tubercle, somewhat proximal to the bony attachment of the tibial collateral ligament and distal to the area in which the tendon of the adductor magnus is fixed. The shadow may appear as a short straight line. When it is more than a centimeter in length it appears to have the shape of a curved line and is more or less parallel to the curve of the tubercle. Further length of the line is usually acquired proximally and is formed by a reversal of the curve so that on roentgenographic examination of the right knee, it has the shape of a flat letter "S." The newly formed curved portion is somewhat further from the cortex of the bone than the original straight part. These facts indicate to us that the tissue in which the lime salts are deposited is not part of the bone but overlaps the tubercle fairly intimately so that it is convex. When the length is greater its proximal portion curves gently in the opposite direction to be parallel to the concavity of the bone contour above the condyle.

A more direct examination of the involved structures was permitted by the findings at operation. The skin incision, which ran longitudinally over the adductor tubercle, was carried through the subcutaneous fat to the fascia lata. This was then incised to expose a white fibrous membrane that seemed to invest the medial aspect of the condylar expansion of the knee. It covered the tibial collateral ligament, the adductor tubercle, and the attachment of the tendon of the adductor magnus. When incised at the level of the adductor tubercle the undersurface of this layer was found to be adherent to an osseous button-like plaque, that was apposed to the tubercle and was molded over it, yet was not part of it (Fig. 3). When the bony plaque was removed, the tubercle was found to be somewhat less polished in appearance than it usually is, but it was covered by a thin periosteal layer. No connection could be found between the dissected area and the inside of the joint. Indeed, when in the course of the operation the joint was entered, it was observed that about 2 centimeters separated the uppermost medial part of the inner joint space from the area exposed by the excision of the mass. It appeared, therefore, that the capsular layer that surrounds the synovial membrane was adherent to the inner aspect of the femoral

From the Northington General Hospital, Tuscaloosa, Alabama.

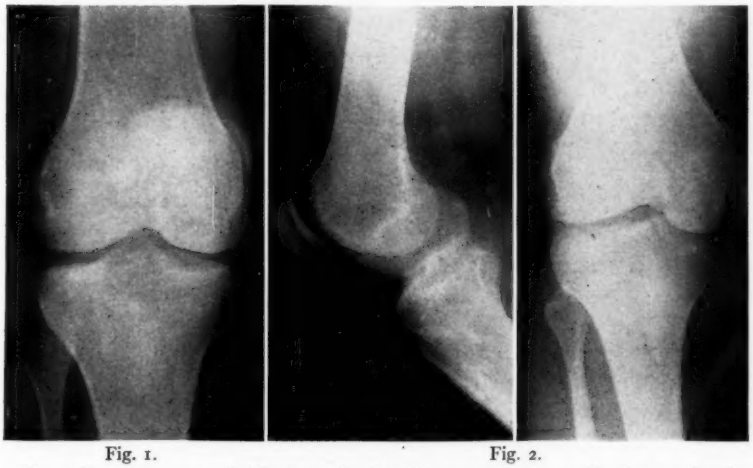


Fig. 1. Fig. 2.

Fig. 1. Roentgenogram of right knee showing the extra-articular ossification overlapping the adductor tubercle.

Fig. 2. Roentgenograms showing calcified mass medial to area of adductor tubercle at some distance from the tibial collateral ligament and separated from cortex by radiolucent line.

condyle below the level of the adductor tubercle and that over this there ran a layer of tissue, which covered the tibial collateral ligament, the adductor tubercle, and the adductor magnus tendon (Fig. 4).

An attempt was made to identify this outer layer in standard textbooks and atlases on anatomy, but most of these references are rather brief in their descriptions. Because of this, dissections were made on routine cadavers in the anatomic laboratory.[1] It was found that beneath the fascia lata there existed an aponeurotic layer that hugged the medial aspect of the knee rather closely, covering the tibial collateral ligament, the adductor tubercle, and the tendon of the adductor magnus. This membrane was not firmly attached to the underlying tissue, and, indeed, seemed to glide over it. When the knee was fully extended and forcible abduction was attempted, the aponeurosis was seen to glide distally over the tubercle. The amount of movement was not great, but a pin stuck through the layer and anchored in the periosteum was clearly tilted distally by this maneuver.

Dissection of a knee at autopsy, immediately post mortem, revealed similar structures, but indicated more accurately the state of the tissues. When the fascia lata was incised and retracted, the membrane that covered the medial skeletal structures of the knee was found to be glistening and white. Three small veins ran parallel to each other within the membrane coursing longitudinally from the upper part of the incision over the adductor tubercle to disappear in the deeper structures at about the level of the knee joint. The membrane glided easily over the underlying tissues and could easily be dissected off to expose the tibial collateral ligament, the tendon of the adductor magnus, and the clear polished adductor tubercle covered only by its periosteum.

[1] Dr. Charles M. Goss and Dr. Margaret Long of the Anatomy Department of the University of Alabama Medical School kindly made available to us the anatomical dissections reported.

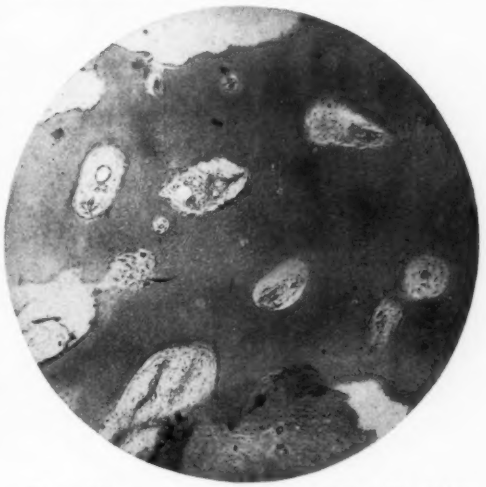
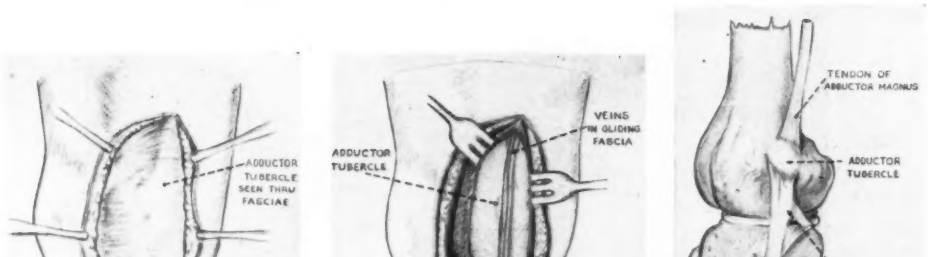


Fig. 3. Microscopic section of plaque seen in Fig. 1 showing structure of bone.

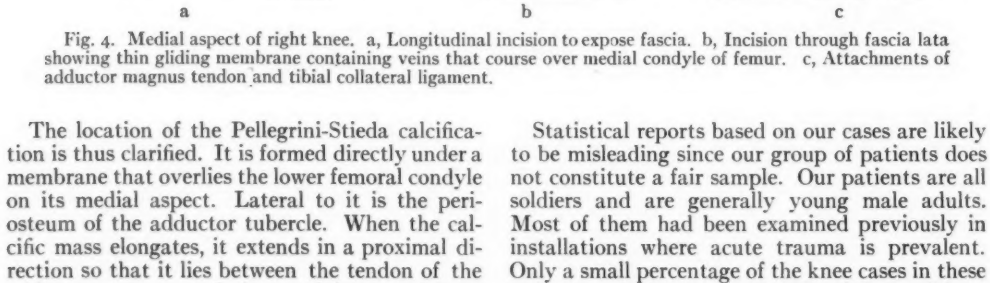


a b c

Fig. 4. Medial aspect of right knee. a, Longitudinal incision to expose fascia. b, Incision through fascia lata showing thin gliding membrane containing veins that course over medial condyle of femur. c, Attachments of adductor magnus tendon and tibial collateral ligament.

The location of the Pellegrini-Stieda calcification is thus clarified. It is formed directly under a membrane that overlies the lower femoral condyle on its medial aspect. Lateral to it is the periosteum of the adductor tubercle. When the calcific mass elongates, it extends in a proximal direction so that it lies between the tendon of the adductor magnus and the overlying membrane. The condition is not due to a fragment of bone from the femur, a tear of the periosteum, or a calcified bursa.

Statistical reports based on our cases are likely to be misleading since our group of patients does not constitute a fair sample. Our patients are all soldiers and are generally young male adults. Most of them had been examined previously in installations where acute trauma is prevalent. Only a small percentage of the knee cases in these units are sent to us. Nevertheless it is possible to make some hypothesis as to the formation of the lesion by considering the histories and the clinical findings.



a b c

Fig. 5. Roentgenograms displaying development of calcification in a "weak" knee that buckled to permit fall August 9, 1943. a, August 9, 1943, "arthritic spurring evident," b, September 16, 1943, wollen soft tissues overlying adductor tubercle show faint calcification. c, December 2, 1943, soft tissues less swollen but calcification distinct.

The calcification has generally been attributed to an injury consisting of a twist of the knee joint. In our patients an attempt was made to determine if the condition was developed with or without an injury. If an injury had been sustained, the patient was asked if he had had a direct blow or an indirect trauma, such as a twist of the knee joint. The histories were not entirely clear in all cases. Six patients gave histories of sprains or twists of the knee, but only a few of them recalled in what direction the leg was forced. Two patients reported direct blows on the joint, but of these only 1 indicated that he was struck on the medial aspect of the knee. Three patients had had twistings with apparent recovery, but later sustained direct blows in automobile accidents or when falling on their knees on the obstacle course. Two patients denied having had any injury whatsoever. Their knee complaints constituted only a part of a polyarticular arthritis. Two did not recall any injury and in the remainder the records are not clear. It appears therefore, though major trauma is found in most of these cases, that it was not the indispensable agent in the production of the condition. It is significant that in all of these patients there was evidence of arthritis in the adjacent knee joint. Examinations revealed thickening of the capsule, occasionally there was fluid increase, and on rare occasions there was limitation of motion. All roentgenograms showed the bony lippings that are considered manifestations of arthritis. Since these changes are not produced immediately after an injury it must be deduced that joint inflammation had been present for some time prior to the precipitating injury. Indeed, one was able to obtain from the patients the history that the knee joints had been troublesome for months or even years before the examination that revealed the calcific masses. The pains in the knees were chronic, some being attributed to a weak joint while others were considered rheumatic. Since chronic inflammatory involvement of the knee was always coexistent it deserves consideration as an etiologic factor. Though the calcified mass is outside of the joint, the hyperemia associated with the inflammation of the joint proper does affect the environs, and so supplies an important liaison between the two areas of pathology.

The element of trauma may be supplied by a single severe tear, but may also be the result of cumulative wear and tear produced by friction of the membrane as it glides when the joint moves. Since the adductor tubercle projects medially it must form a local factor irritating the fascia that moves over it. Any abduction of the knee joint must produce a strain on the membrane particularly where it stretches over the promontory of the tubercle. The area under consideration is thus vulnerable to degenerative irritations as well as to tearing strains. On the other hand the frequency of ruptures of the supportive structures of the knee on the medial aspect, *without* the subsequent development of the Pellegrini-Stieda complication, leads one to question any hypothesis that the rupture alone can produce this complication. Furthermore, in none of our cases was the injuring force of such magnitude that a major laceration of the medial soft tissues took place. In none of them did the sprain lead to an instability of the knee that would suggest a major lack of support on this side. Even the more severe twists were *strains* rather than severe *sprains*. All of these factors make us believe that the series of events leading to the formation of a calcific deposit is as follows. A process of attrition takes place on the inner aspect of the gliding membrane over the critical point, namely the adductor tubercle, where friction can most easily be obtained. This process may have its origin in a series of small traumas that do not attract much attention. The process of attrition will be speeded by the swelling of the tissues that is induced by either polyarticular (systemic) arthritis or local traumatic arthritis of long standing (Fig. 5). As a result of the degenerative process affecting the undersurface of the membrane, the tensile strength is reduced so that a relatively moderate injury may cause an incomplete tear. This rupture is associated with a laceration of small blood vessels such as we have seen

Fig. 6. Ossified mass overlying adductor tubercle. Even though photograph is reduced, organization of mass, with cortical periphery and trabeculated center can be recognized.

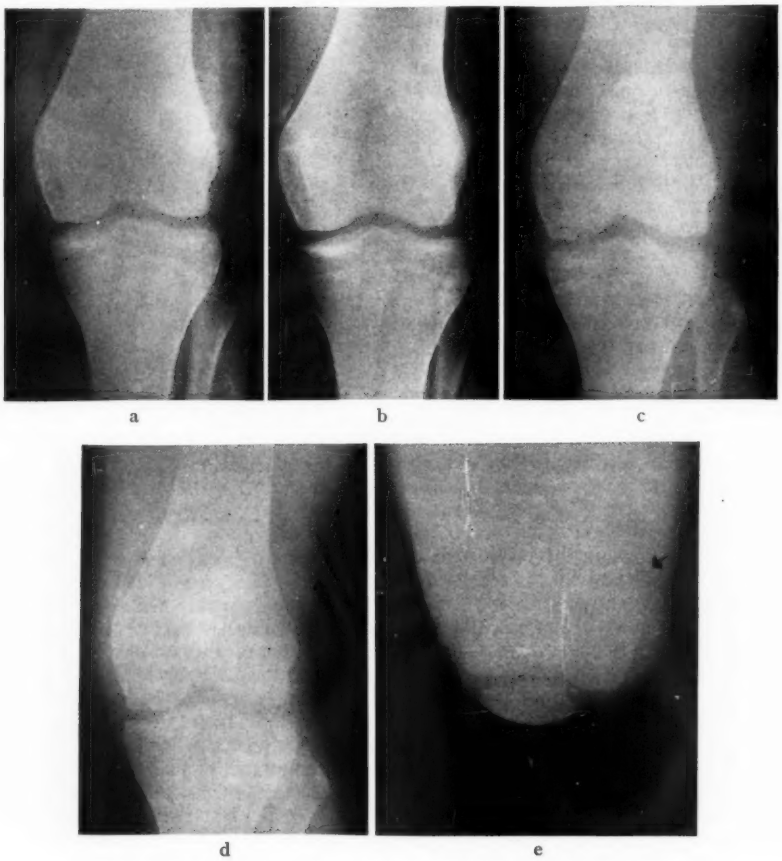


Fig. 7. Serial roentgenograms showing development of para-articular bony plaque. Knee, "twisted" in football in 1940, had remittent periods of swelling and pain without major injury. a, September 14, 1943, roentgenogram of knee immediately after a fall produced by buckling shows swelling of soft tissues over medial femoral condyle. b, October 21, 1943, calcification is seen near adductor tubercle. c, November 12, 1943, calcified mass is smaller but more organized. d and e, December 20, 1943, anteroposterior and tangential views show plaque near femur but not attached to it.

in our dissections and permits a moderate amount of bleeding to take place. The tear is not of such magnitude that a large hemorrhage is formed or that it opens avenues of escape for the bleeding through fascial planes. The small hemorrhage is trapped locally, and is molded in its position by the outer coating of the membrane. The encapsulated hematoma thus formed undergoes degenerative changes which, under the proper physical and chemical conditions, lead to the calcification. The exact nature of these conditions has not been demonstrated in our cases. It has, however, been shown elsewhere that blood contains within itself the elements that are necessary to produce calcification in areas where the calcium and phosphorus concentration is adequate and where a relative alkalinity exists. The blood cells and plasma have within them acid esters of phosphorus, as well as the phosphatase that is necessary to convert them into inorganic phosphate. Whatever the theory for local calcification may be, the fact remains that calcification of hematomas is a well known occur-

rence. An early step is the deposition of lime salts in the form of calcium phosphate granules. The granular nature of the shadow is shown in our roentgenograms. Under some conditions of repair this unformed granular mass can be absorbed. In other instances, however, there is a gradual organization of this mass that leads to the formation of bone (Fig. 6). This phase too, is demonstrated in our serial roentgenograms (Fig. 7). The specimen we were able to examine represents this stage (Figs. 1 and 3).

We find many analogous circumstances in the shoulder where similar lesions occur. These have been intensively studied. The supraspinatus tendon, running as it does over the head of the humerus, is subjected to a considerable amount of friction as the result of the movement of the arm. In spite of the intervening bursa there is a great deal of attrition going on in patients who use their shoulders excessively. The degenerative changes affect not only the bursa but also the adjacent surface of the tendon. Incomplete tears of the tendon have been demonstrated in many instances. The precipitation of lime salts in these areas is by no means uncommon. At first there is a soft, creamy mass which becomes gritty at a later stage and not infrequently becomes organized into a definite body of bone. Microscopic examination of the tissues before organization has taken place reveals that there is a low grade inflammatory process in the soft tissues in which the precipitation takes place. We believe that the process of calcification at the knee joint is quite similar to that of the shoulder.

SYMPTOMS AND PHYSICAL FINDINGS

It is rather interesting that when our patients were asked to localize the pain in the knee they pointed to the area just below the patella. None of them indicated the region of the adductor tubercle. Since we did not see them immediately after the injury that led to the calcification, they were asked if they had had pain near the tubercle. None of them recalled any acute discomfort in this area. Many of them had some discomfort in the knee at the extremes of extension and flexion. Some of them had an ache that was present particularly on weather changes and when they first arose from a sitting position. Others complained that prolonged walking made the knee hurt. On examination one could feel the thickened capsule and an occasional case had fluid increase. Pressure over the articular edge of the tibia produced pain in every case. Palpation of the adductor tubercle revealed some local fullness which felt bony in character. When compared to the corresponding area on the unaffected knee there was a distinct though not large bony prominence. In none of our cases could we move the calcified mass over the underlying bone. Pressure on this area gave discomfort in about half of the cases but at no time was tenderness great. We believe it possible to recognize clinically the existence of such a calcified mass in a large percentage of the patients if, in addition to the usual examination procedures for injured knees, we add careful palpation in the region of the adductor tubercle. Of course, after the local lesions have become radio-opaque, roentgenographic examination will reveal their existence.

TREATMENT

Since the calcified mass is extra-articular and is so situated that it does not irritate tissues within the joint proper, the knee joint and the Pellegrini-Stieda calcification must be treated independent of each other. The articulation constitutes a problem that is not germane to this paper and must be treated on its own merits. The calcified mass in our group of cases has not been a significant source of discomfort to the patients. It is conceivable that in the acute stage there may be an appreciable local irritation associated with the newly calcified bone, and lavage of the precipitated lime salts may prove as valuable as it does in the shoulder calcification. We have had no experience with this procedure. Physical therapy in the form of local heat may have some value in clearing up the calcification, having been given to 2 of our patients in whom the lime salts disappeared. Roentgen therapy likewise suggests itself as a therapeutic measure, though we have not applied it in these cases. Surgical intervention is in our opinion rarely necessary. Inasmuch as the symptoms connected with these are relatively insignificant, it is conceivable that if the mass is large enough to cause increased irritation on the investing membrane further attrition of this layer at the critical point may take place. In such circumstances removal of the plaque may be indicated. If surgery is contemplated one must recall the injunction made by Kulowski not to add the trauma of surgery to the area before the calcification and organization have been complete. Otherwise one may find a return of calcification in the scar of the operation. In our patients the only one that was subjected to operation had the bony mass removed because an arthrotomy was necessary for the removal of a joint mouse, and the Pellegrini-Stieda calcification could be removed at the same time without much trauma. Eleven of our patients were returned to full active military duty. Those who were not were separated from the service for

reasons other than the calcification. Since only 1 of our cases had the calcified mass removed and since all had been given an opportunity to exercise their extremities before they were discharged from the hospital, we feel that the Pellegrini-Stieda calcification does not entail any appreciable disability.

COMMENT

The imposing name of "Pellegrini-Stieda disease" is misleading. It implies that the one finding of the calcification over the adductor tubercle is a disease complex. The stress that is given this particular manifestation tends to detract from what is usually the significant part of the patient's disease, namely the arthritis of the knee joint. Furthermore because of the visualization of this anomaly there has been a tendency to associate the symptoms of the affected knee with it. This belief has led to surgical intervention for the removal of the mass. In our opinion such an approach to the problem is inaccurate in that it stresses a relatively innocuous manifestation and tends to overlook the major disabling factor.

SUMMARY

1. Twenty patients with calcification over the adductor tubercle are reported, and the operative findings in 1 case are described.

2. A description is given of anatomic dissections and 1 autopsy exploration of the area under consideration. These studies revealed the existence of a membrane which we consider an important factor in the formation and shaping of the calcified mass.

3. The coexistence of chronic arthritis of the knee is stressed.

4. A hypothesis as to the etiology of the calcification is presented.

5. Attention is directed to its relative clinical insignificance.

6. Conservatism in treatment is stressed.

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THENAR PALSY DUE TO COMPRESSION OF THE MEDIAN NERVE IN THE CARPAL TUNNEL

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IN 1909 Hunt described a curious syndrome, characterized by gradual atrophy of the radial part of one or both thenar eminences, the result of paralysis of abductor brevis and opponens pollicis. The short flexor of the thumb is usually spared; there is no fasciculation; the reaction of degeneration is present in the affected muscles; and the condition never involves the interosseous or hypothenar muscles. Sometimes there is subjective sensory disturbance in the tips of the digits but usually no demonstrable loss of touch or pain sensibility. The patient is usually middle aged or old.

Hunt, 1909, 1911, described 3 cases and regarded them as occupational palsies, due to repeated firm pressure on the branch to the thenar muscles at a particularly vulnerable point where it turns forward over the lower border of the anterior carpal ligament. Wartenburg (1939) challenged this theory because of its incompatibility with Saunders' finding that the median nerve motor branches are nearly always covered by a slip of muscle, either flexor or abductor pollicis brevis.

Marie and Foix (1912), in describing a series of cases of isolated muscular atrophy of the hand, mentioned one which tallied exactly with those of Hunt, but they ascribed the condition to syphilis since the patient had lightning pains in the leg and the ankle jerks were absent. There were no other signs of central neurological disturbance. Later (1913), they performed a necropsy on a patient suffering from a similar paralysis; unfortunately it had not been possible to test sensibility satisfactorily since the patient was over 80 and hemiplegic. They found a neuroma on the median nerve, just proximal to the anterior carpal ligament and a constriction of the nerve trunk beneath the ligament. Histological examination of the neuroma revealed a decrease in the number and size of the myelinated fibers and a noticeable increase in the interfascicular connective tissue. At the site of constriction, there was gross fibrosis within very small bundles, and distal to this complete degeneration of the fibers.

Brouwer, 1920, recorded 15 cases and favored a phylogenetic explanation. He suggested that the thenar muscles, being recently acquired characteristics, are more susceptible to trauma and under adverse conditions more liable to undergo degeneration than other muscles.

Harris, 1926, mentioned wasting of abductor brevis and opponens without sensory loss as a complication of arthritis of the trapeziometacarpal joint.

Lhermitte and de Massary, 1930, recorded the necropsy on a patient suffering from this syndrome in which there was atrophy of the dorsolateral nuclei in the sixth and seventh cervical segments of the spinal cord.

Dorndorf, 1931, described 16 cases, all women at or about the menopause—a factor which he considered significant. He suggested that there was a toxic neuritis affecting motor fibers more than sensory.

Moersch, 1938, who added 1 case, supported the view of Hunt that the motor branch is injured as it passes over the distal edge of the anterior carpal ligament.

Wartenburg, 1939, presented 7 further examples. He dismissed the possibility of median nerve compression because nearly all the recorded cases affected only the outer part of the thenar eminence, and there was seldom any sensory disturbance. His views are similar to those of Brouwer.

Woltman, 1941, reported 2 cases of thenar palsy, 1 of which had slight sensory loss in the median area and was associated with acromegaly. The other, a woman of 71 with arthritis of the wrist, had a complete median nerve lesion, with motor and sensory loss. She made a perfect recovery after section of the anterior carpal ligament by Learmonth, an indication that the paralysis was due to compression of the nerve trunk. He suggested that the nerve may become compressed by an increase in intraneural connective tissue, as in acromegaly, or by narrowing of the carpal tunnel due to periarticular thickening.

The explanations of the thenar palsy offered in these papers can be summarized as follows: (1) pressure on the motor branches of the median nerve at the distal end of the anterior carpal ligament; (2) phylogenetic susceptibility of the thenar muscles; (3) compression of the median nerve in the carpal tunnel; and (4) a spinal lesion.

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Fig. 1. Case 1. Bilateral wasting of the lateral portion of the thenar eminence.

Evidence is strongest in favor of the third hypothesis; yet the 2 cases cited in support of this view were not proved to be identical with the others, although there were similarities. The following 2 cases are presented because they showed predominantly motor lesions; only the radial part of the thenar eminence was affected; and in both it was clearly proved that the median nerve was compressed in the carpal tunnel.

CASE 1. J. R., a skilled mechanic, aged 63 years, first noticed wasting of the left thumb muscles in 1930, and later some sensory impairment on the palmar surface of the first, second, third, and part of the fourth digits. In 1940 a similar condition arose in the right hand and was accompanied by paresthesia in the tips of the radial 3 digits. Early in March, 1944, extension of the second and third digits became difficult and finally impossible. His general health had been very good, and there were no other complaints. The only significant feature of the past history was a strain of both wrists some time between 1900 and 1910.

On examination, May 22, 1944, there was no general neurological disturbance and no skeletal abnormality above the wrists.

The left thenar eminence was very wasted (Fig. 1). Abductor pollicis brevis and opponens were paralyzed. Flexor brevis was strong, and there was no weakness of the ulnar intrinsic muscles. Sensibility was dulled but not lost on the tips of the thumb and index. The index and medius were flexed at all three joints and the power of extension of these fingers was virtually lost.

The right hand presented a similar picture except that the wasting and weakness of the muscles were less, and there was no loss of extension of the fingers. Electrical testing showed reaction of degeneration in abductor brevis but normal faradic excitability in the short flexor. Median nerve stimulation produced no response in the thenar muscles, whereas flexor pollicis brevis contracted on ulnar nerve stimulation at the wrist.

On both wrists, particularly on the left and on the dorsum, there were soft, deeply situated swellings resembling ganglia. There was no clinical or radiological evidence of cervical rib, the blood count and sedimentation rate were within normal limits and the Wassermann reaction was negative.

Radiography revealed old fractures of both scaphoids with osteoarthritis (Fig. 2).

These clinical findings strongly suggested low median nerve lesions of the dissociated type, motor fibers being

Fig. 2. Case 1. Bilateral fractured carpal scaphoids with osteoarthritis of wrists.

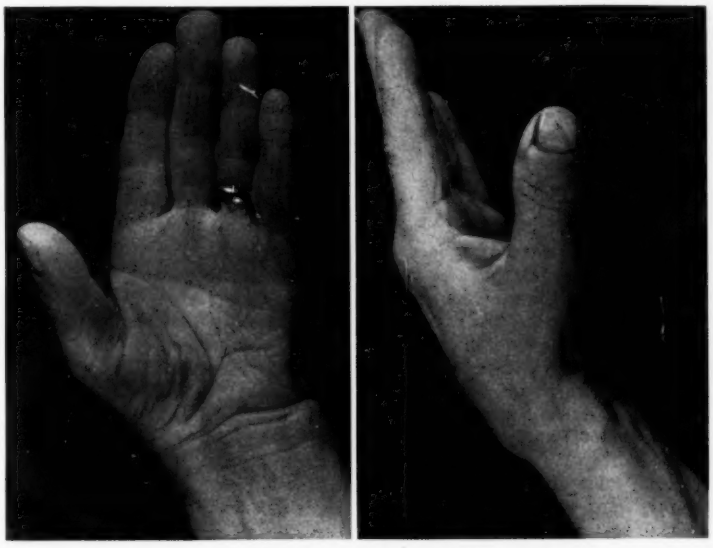

Fig. 3. Case 2. Wasting of lateral portion of left thenar eminence.

more affected than sensory. There was an associated traumatic osteoarthritis of the wrists that had produced a very considerable periarticular swelling.

At operation, June 14, 1944, by Professor Seddon, the left median nerve was exposed at the wrist and in the carpal tunnel, where it was found to be compressed between the anterior carpal ligament and the floor of the tunnel: when released the nerve was seen to be narrowed. The loss of extension of the interphalangeal joints of the second and third digits may have been due to weakness of the first and second lumbricales, but the defective extension of the metacarpophalangeal joints was not explained.

A piece of the soft tissue swelling on the back of the wrist was removed: it consisted of a fatty fibrous tissue with some normal synovia. In addition some fibrous tissue from the tendon sheath showed a number of clefts and pseudocysts.

Examination on September 4, 1944, showed no recovery in the paralyzed thenar muscles and no improvement in sensibility in the radial three digits.

Case 2. Mrs. A. H., aged 68 years, sustained a fracture of the left wrist about 1920. The fracture was not reduced and there was a persistent deformity. Early in 1943 she noticed tingling in the median area of the hand with spontaneous pain in the thumb, aggravated by use. The thumb had become weak and the defective grip was disabling.

On examination, February 7, 1944, there was found the typical deformity of a malunited Colles' fracture. The radial part of the left thenar eminence was wasted (Fig. 3). Abductor pollicis brevis was paralyzed and opponens weak (3—Medical Research Council grading of muscle power). Flexor brevis and the ulnar intrinsic muscles were normal. There was reaction of degeneration in the short abductor of the thumb but a normal response in the short flexor, which also contracted on ulnar nerve stimulation. There was no demonstrable sensory disturbance and sweating was visible in the median area.

Radiographically there was a malunited Colles' fracture (Fig. 4) with a large bony mass projecting forward from the lower end of the radius. There was no cervical rib.

At operation on June 10, 1944, by Professor Seddon, the median nerve was exposed at the wrist under local anesthesia. At the anterior carpal ligament the nerve turned sharply backward and took a steep dive beneath it, being closely compressed on its lateral and superficial surfaces between the ligament and the lower end of the radius. The anterior carpal ligament was divided and the nerve

Fig. 4. Case 2. Malunited Colles' fracture.

was seen to be flattened and slightly reduced in diameter. There was no doubt that the local constriction was the cause of her symptoms.

Paresthesia and pain were completely relieved within 2 days after operation. August, 1944, recovery in abductor pollicis brevis and complete relief from the sensory disturbances.

DISCUSSION

It has been shown that various authors have postulated lesions of the motor branches, the muscles, or the anterior horn cells, but rarely the main trunk of the median nerve, to account for the almost purely motor character of the lesion and the exclusion of the short flexor of the thumb.

The sparing of the short flexor is easily explained. In common with many other workers Hunt, 1908, recognized that the thenar muscles may be partly supplied by the ulnar nerve, although Wartenburg did not accept this view. More recently, it has been shown by Highet, 1943, that in about 3 cases of 4 the flexor pollicis brevis receives part or all of its nerve supply from the ulnar nerve: an examination of many more patients by us has confirmed this finding, for in a high proportion of median nerve divisions, flexor pollicis brevis is still acting. That this was the state of affairs in the 2 cases described was shown by faradic stimulation of the ulnar nerve, and a similar explanation is likely in the previously reported cases. But it is not surprising to find that in some instances, e.g., Woltman's case and some of those cited by Dorndorf, all the thenar muscles were affected, since there is a minority of subjects in whom flexor pollicis brevis is supplied entirely by the median nerve.

The second source of difficulty in diagnosis is the almost complete absence of sensory disturbance; this has led previous authors to inculpate the motor branches of the nerve (Hunt), the muscles themselves (Brouwer and Woltman), or the anterior horn cells (Lhermitte and de Massary). Another explanation is possible. It is known that moderate trauma may affect a nerve selectively so that one function is suppressed with little or no change in others (Stopford, 1926). Recently, Sanders and Seddon (unpublished work) have shown that in traction injuries the larger fibers—motor and proprioceptive—suffer more than the smaller ones, and this dissociated type of lesion is frequently encountered in peripheral nerve lesions from many causes.

In Case 1, there was a mild sensory disturbance at the finger tips, whereas in the other there was no demonstrable sensory disturbance at all; yet in both the site of the lesion was undoubtedly the main trunk. Moreover, subjective sensory disturbances were present in one of Hunt's 3 cases, and in 5 of 7 of those reported by Wartenburg, in 2 of which there was demonstrable mild impairment of sensibility.

In patients presenting this syndrome there are, therefore, good grounds for suspecting a lesion of the main trunk of the median nerve, and the possibility of compression of the nerve in the carpal tunnel must be borne in mind.

The cause of the compression may be quite obvious as in the case of the malunited Colles' fracture, and a number of examples of this have been recorded. Most of these lesions followed the injury within 1 or 2 months (Bouilly, 1884; Lewis and Miller, 1922; Abbott and Saunders, 1933) and the sequence of events was then quite clear. In only a few recorded cases did it occur as a late sequel; Abbott and Saunders reported one example occurring many years after the injury and quoted two others.

Fractures of the carpal bones, especially the scaphoid, are a fruitful source of osteoarthritis of the wrist, and if there is much periarticular swelling narrowing of the carpal tunnel is ultimately inevitable.

Several of the cases reported by Brouwer and Dorndorf, and one of Woltmann's had arthritis of the wrist.

It is possible that other factors may produce the same state of affairs, but there is undoubtedly sufficient evidence to demand a careful investigation of the local condition in every case of this syndrome, if only to exclude compression of the main nerve trunk in the carpal tunnel.

The early release of the nerve by division of the anterior carpal ligament may lead to recovery of motor power, but, if the paralysis and wasting have been present for many years, it is unlikely that recovery will occur since the changes in the muscles will have become irreversible. The contrast in the 2 cases presented is very striking: in Case 1 the paralysis had been present for 14 years and there was no sign of recovery 3 months after operation. In Case 2, the symptoms had been present for only 15 months, and within 2 months of releasing the nerve abductor pollicis brevis had recovered.

SUMMARY

1. Two cases of the syndrome of partial thenar atrophy are presented.

2. The paralysis was due to compression of the main trunk of the median nerve in the carpal tunnel.

3. The partial nature of the atrophy is due to ulnar innervation of flexor pollicis brevis.

4. The almost complete sparing of sensory fibers is probably due to the selective action of the

trauma, affecting the large fibers (motor) predominantly and producing a dissociated type of lesion.

5. Division of the anterior carpal ligament is suggested as a means of relief.

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DECIDUAL REACTION OF ENDOMETRIUM ECTOPIC IN AN ABDOMINAL LYMPH NODE

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MASSES of tissues with the structure of endometrium, heterotopic in pelvic lymph nodes, have interest because no theory as yet seems to explain their formation. The proper identification of these heterotopic tissues is somewhat in doubt when they are found in the quiescent stages, and only general structural similarities are available for comparison with uterine mucosa. Specific physiologic changes such as a decidual reaction of the stroma cells in these heterotopic tissues simplifies the identification. Emil Ries, in 1897, described gland tissues in iliac lymph nodes and concluded they were remnants of the Wolffian body, although he mentioned their similarity to endometrial glands. Wertheim, in 1900, reported gland structures in lymph nodes which at first he believed were metastatic from an adenocarcinoma of the cervix. Later he revised this view when he observed similar gland tissues in pelvic lymph nodes of patients dying from noncancerous diseases. Descriptions of these heterotopic tissues by Wuelfing, in 1901; Manteufel, in 1904; Meyer (27) in 1909; and others were interpreted as metastatic carcinoma. Some believe these structures arise from lymphatic endothelium. Schindler, in 1906, suggested that these heterotopic tissues of lymph nodes may be displaced endometrium and Geipel, in 1916, described decidual reactions in them. He studied pelvic lymph nodes from the bodies of 13 women, dying from complications of pregnancy and found the endometrial tissues most frequent in the hypogastric and less often in the sacral lymph nodes. The foci of decidual cells were found in the capsular and cortical portions of the lymph nodes, usually as discrete foci and as large as a lymph follicle. There was either a single large mass of tissue or multiple small foci. Geipel observed multiple glands lined by cuboidal or columnar cells and concluded that they were derivatives of the Wolffian duct. More recent reports of heterotopic endometrium in pelvic lymph nodes were published by Halban, 1924, Hosoi and Meeker, 1929, Hansmann and Shenken, 1933, and others. Schiffman and Seyfert, and Polster stated that the regional distribution of heterotopic endometrium usually coincided with the location of ectopic decidual tissues, and that the incidence of these two conditions decreased as the distance from the ovary increased. According to Meigs the stroma cells of about half of these heterotopic tissues manifest physiologic activity. Goodall has observed endometrial tissues with and without physiologic changes in the same heterotopic location.

Gland-like structures have been observed also in lymph nodes in the axilla, the neck, and in the parotid and submaxillary regions by Sternberg, Carere-Comes, and others.

A negress, aged 34 years, died 10 minutes after admission to St. Luke's Hospital. The postmortem examination demonstrated, as the cause of death, a huge hemoperitoneum. Bound to the left side of the uterus was a mass of hemorrhagic tissue, the posterior surface of which was torn, and opened into a ruptured fetal sac, containing a fetus with a crown rump length of 6.5 centimeters, and an overall length of 12 centimeters, attached by an umbilical cord 13 centimeters long and 4 millimeters in diameter to a torn placenta in the hemorrhagic tissues. The left ovary was in front of this mass and bound to the left horn of the uterus. It contained a corpus luteum of pregnancy 2.5 centimeters in diameter. The left fallopian tube was not identified in the hemorrhagic tissue. The right fallopian tube and ovary were bound to the enlarged uterus. The lining of the uterus was pale grey and ranged to 5 millimeters in thickness. Histologic preparations from the hemorrhagic mass contained linings of the amnion and chorion continuous at one level with hemorrhagic and necrotic decidual tissues, and chorionic villi. There were focal exudates of lymphocytes and plasma cells. These tissues were bound to the fibrous wall of the left fallopian tube. In serial sections, a small pelvic lymph node contained, in the cortex, several tubules lined by tall columnar epithelium and surrounded by decidual tissues (Figs. 1 and 2). Another tubule, in the medullary portion, was in a small amount of fibrous tissue.

No satisfactory explanation has been offered for these heterotopic endometrial tissues with or without decidual reactions. Several theories have been proposed. Von Recklinghausen, in 1896, stated that aberrant adenomyomas developed from remnants of the Wolffian ducts, and these have also been considered as potential precursors of decidual tissues (19). Others have believed that these tissues develop from lymphatic endothelium or regional elements in the pelvis from a chronic inflammation, the action of cancerous tissues, or a hormonal influence. Iwanoff, Meyer (26), and others stated that the pelvic peritoneum,

From the Henry Baird Favill Laboratory of St. Luke's Hospital. Aided by the Winfield Peck Memorial Fund.

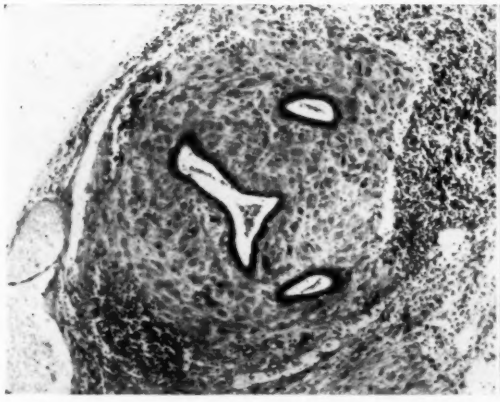

Fig. 1. Photomicrograph (low power) of mass of ectopic endometrium under capsule of a pelvic lymph node.

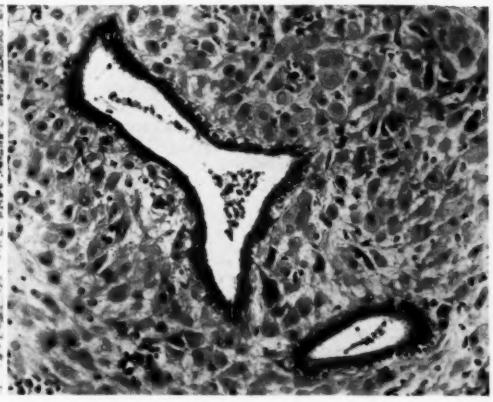

Fig. 2. Photomicrograph illustrating the decidual cells about the gland structures. ×130.

derived from celomic epithelium, is potentially capable, under certain conditions, to undergo metaplasia, and produce mullerian-like ducts and tubules. Weller expressed a similar view, and stated that the subserous stroma cells of the peritoneum could form masses of decidua about these heterotopic gland structures. Schiller (39, 40) stated that in early fetal life the entire peritoneum is potentially able to form endometrium, but, in the course of normal development, only the peritoneal cells in the mullerian region retain this potency which may remain latent for years, and then, as a result of stimulation, may be activated, and form regions of endometrium within the peritoneum. Halban, Schindler, Carere-Comes, and others concluded that endometrial tissues migrate into the lymphatics, draining the uterus, during menstruation, and are carried to extrauterine locations. Sampson (33, 34, 35, 37) has proposed that a retrograde flow of menstruation products occurs. The cast-off viable endometrium, he stated, is implanted throughout the pelvic peritoneum. According to Sampson, endometrium is displaced also through venous and lymphatic channels, more frequently by the veins than the lymphatics. Goodall believed that endometrium becomes invasive as a result of faulty ovarian secretion, but stated that lymphoid tissue and tissues outside the pelvis are unsuitable for the growth of heterotopic endometrium. H. O. Jones stated that these heterotopic tissues may come from either the superficial two-thirds of endometrium or the basal layer, and that specific physiologic changes occur more readily when the more responsive superficial layers are involved. Possibly some of these heterotopic tissues may be more immature than others, and hence, incapable of functional activity, and decidual reactions occur in stromal cells of the heterotopic endometrium only after functional maturity has been reached.

Gland-like tissues in lymph nodes of the mesentery near the pancreas, in the neck, and around the salivary glands, according to Carere-Comes, may come from embryonal displacements of tissues. Sternberg said if endothelial proliferations in lymph vessels lead to epithelium-like formations, it would be difficult to believe that such a transformation should confine itself to the border sinuses of lymph nodes, without changes in the endothelium elsewhere. He concluded that epithelial cells from these glands migrated through the lymphatics to regional lymph nodes, and formed small glandular inclusions.

CONCLUSIONS

1. Heterotopic endometrial tissues with decidual reaction of the stroma cells were found in a pelvic lymph node of a woman who died from the hemorrhage caused by a ruptured extrauterine pregnancy.

2. The decidual reaction of the stromal cells in these heterotopic tissues indicates that these tissues, during the term of pregnancy, have the physiologic changes of endometrium in the uterus.

3. Of the theories proposed as to the origin of heterotopic endometrium, none, as yet, has been accepted generally. Probably the factors involved apply also to the origin of glandular structures observed in lymph nodes in other regions of the body.

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EDITORIAL

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AUGUST, 1945

GASTROSTOMY

FROM a survey of the large number of operative techniques developed for the performance of a gastrostomy, one might gather that a large field of usefulness existed for this procedure. Undoubtedly the most common lesion for which this operation is performed is a carcinoma of the esophagus, especially of the middle third where the majority of these neoplasms are located. Our experience at the Cook County Hospital has given us reason to reconsider the entire problem.

We have reviewed the records of 80 patients on whom gastrostomies were performed between 1941 and 1944. There were 72 males and 6 females, a frequency in females higher than that ordinarily reported. The ages varied between 51 and 81 years. The classical symptoms of dysphagia, inability to retain liquids and solids, and weight loss were uniformly present. Of particular interest was the average weight loss of 36 pounds in this series of patients. This implies the loss of 16,000 grams of tissue, the most important fraction of which is tissue protein. X-ray examination or esophagoscopy or both usually have demonstrated the lesion before operation. The middle third of the esophagus is involved most frequently, the lower third next, and the upper third the least frequently. Almost one-half of these patients show a secondary anemia when admitted to the hospital. It is certain that the incidence of anemia would have proved to be higher had blood counts been repeated after dehydration had been combatted. In another series of cases previously reported, in which patients required various surgical treatment, an incidence of hypoproteinemia of 23 per cent was found. Hypoproteinemia was considerably more frequent in this group of cases; here again the actual incidence would have been still higher had dehydration been taken into account.

The usual preoperative preparation consisted of the use of antispasmodics, liquid diet where possible, and parenteral fluids and vitamins. Twenty-six of the 80 patients received blood transfusions and in no case was more than 500 cubic centimeters given. The operations were performed by several members of the attending and surgical staff. A variety of anesthetic agents were used; local anesthesia or intercostal block was favored. Average operating time was slightly over one hour. The types of gastrostomies performed included those described by Janeway, Witzel, Spivak, Thorek, and Glassman.

In many instances the gastrostomy was performed with the hope that resection of the esophagus could be accomplished at a later date. Actually, resection was done in only one patient, and in this instance it proved to

be fatal. Thirty-nine of the 80 patients ran a postoperative temperature of 100 degrees or more. Wound infection, wound erosion, retraction, stricture, and necrosis of the gastrostomy stoma, and bronchopneumonia were frequent complications. Two patients died within the first postoperative day, 19 within the first postoperative week, 18 within the first postoperative month, and 4 within the second postoperative month. Thus a total of 43 of the 80 patients operated on died within 2 months of the performance of the gastrostomy! Such results speak for the futility of gastrostomy even as a preliminary procedure in resection of the esophagus.

In the interpretation of these discouraging results, it must be recognized that the patients are malnourished and are quite different from those who come to the attention of the surgeon in private practice. Nevertheless they are typical of the patients seen in the wards of charity hospitals and the number of such patients exceeds that encountered in private practice. Many of the patients come to the hospital already in the last stages of the disease. In spite of this rationalization, gastrostomy *per se* proved to be futile in this group of patients and only hastened their demise. The results prior to 1941 were almost certainly no better if only because parenteral fluid therapy and postoperative care were less adequate then than now.

To improve the treatment in such cases certain problems must be taken into consideration. The most severe degree of protein deficiency encountered in surgical patients is found in these patients. Our group at the Cook County Hospital for the past two years has been interested in protein nutrition and has attempted to achieve a nitrogen balance in 15 patients with carcinoma of the esophagus. Relying exclusively upon parenteral amino acids as the source of protein, it has been necessary to treat these patients with daily intravenous infusions for periods as long as one month before a gain in weight is made. In cases in which blood alone is used as a source of parenteral protein, we learned that it is necessary to administer at least 2000 cubic centimeters before a significant rise in plasma proteins is produced. The high incidence of anemia would further point to the need for whole blood.

With a well prepared patient and adequate nursing service, the procedure of choice in these cases appears to be a transthoracic esophageal resection and anastomosis. If this seems like an "all or nothing" method of attack it should be remembered that since such patients rarely live long enough for resection after gastrostomy, there is everything to gain. Carcinoma of the lower third of the esophagus presents relatively less technical difficulty than does carcinoma of the middle third. After completion of the anastomosis, the introduction of an Abbott-Rawson tube with the aid of a stylette may offer the advantage of maintaining continuous suction at the suture line, at the same time permitting intragastric feedings through the second lumen. Continuous oxygen inhalation is important. Because intrathoracic infection is still the most frequent complication of this type of surgery, the instillation of penicillin through an inlying catheter might offer still another postoperative aid.

KARL A. MEYER
DONALD D. KOZOLL

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REVIEWS OF NEW BOOKS

GIVEN, an aspect of investigation that is fundamentally important, that has been actively pursued for a long period, that has been the subject of controversy, yet one on which every person in the subject has an opinion, of clinical as well as theoretic importance; take such a subject, and select its most outstanding workers to write a summary of the evidence for their views, edit it and produce it well, and the result is certain to attract widespread attention and occupy a permanent place in the scientific literature.

Certainly, the cortical control of movement is such a subject. Indeed, the subject has attracted some of the most able workers in neurology in this country, so that the list of contributors to *The Precentral Motor Cortex*[1] includes many of our top experimental neurologists. Though the work was edited and produced at the University of Illinois it is not to be regarded as representing exclusively the views of the men of that institution, as only 4 of the 15 contributors are on its faculty. The sections of the book vary widely in scope. Von Bonin's, Walker's, Bucy's and Davison's sections present material for the first time. Others are more in the nature of critical summaries or of reviews.

The first chapter is a study of the cytoarchitectural partitioning of the precentral motor cortex in the monkey, chimpanzee, and man, by Dr. von Bonin.

The article by Dr. O'Leary entitled "Cytoarchitectonics and Electrical Activity" turns out to be a most instructive theoretical account of the relation between the passage of nervous impulses and the oscillographic record, and one that will be invaluable to neurophysiologists. Dr. Walker's section on afferent connections presents new material on thalamocortical relations, found in the human. Dr. Paul M. Levin contributes a short section on efferent fibers based on study of Marchi lesions of monkeys. The subject of anatomical connections of the cortex, afferent and efferent, forms the greatest hiatus in our knowledge of the cortex today, in this reviewer's opinion. Experimental neurophysiologists are many but experimental neuroanatomists are few and badly needed, for the physiological aspect has developed beyond the demonstrations of the connections involved, as is amply shown by Dr. McCulloch's article on cortico-cortical connections. Those to whom the matters of supressor areas, effects of local strychninization and "physiological neuronography" have been getting out of hand will do well to read this clear summary by their chief elaborator. This chapter is not confined to the premotor cortex but includes all parts of the cortex. The problem of the origin of the pyramidal tract is discussed by Dr. Sarah Tower. The somatic and autonomic aspects are reviewed appropriately by Dr. Kennard and the relation to the cerebellum by Dr. Bailey. Dr. Wilbur K. Smith discusses area 8, which has been included because stimulation produces deviation of eyes and head.

Chapters 13 and 17 are mainly clinical. They include an exposition by Dr. Theodore C. Erickson of the results of stimulation in man, supplemented by two chapters by Dr. Bucy on effect of extirpation in man. The clinical symptomatology is discussed by Dr. Charles D. Aring who distinguishes between the effects of lesions in these areas. This chapter is perhaps the most important for the clinical neurologist. Dr. Charles Davison contributes a series of original cases with various confirmed lesions in the premotor region classified by symptomatology.

The last chapter on "significance" by Dr. Marion Hines stresses relation to the muscular mechanism in effecting movements and gives data on the physiological development and responses to stimulation in the fetal and young macaque.

The material would have been made more easily assimilable if the editor had prepared a terminal chapter summarizing the subject by gleaning from all the contributors' viewpoints, but no doubt the editor, Dr. Bucy, would regard this as an abandonment of the principles of free expression of judgment which has guided the preparation of the book. The work has been ably edited, and its fine format and heavy paper are agreeable surprises in these days when books are apt to be sleazy in material and content.

WENDELL J. S. KRIEG.

THE essential aspects in the field of allergy are covered in Criep's *Essentials of Allergy*[2]. There are chapters on the immunology of allergy, anaphylaxis, and serum sickness; on diagnosis and treatment of allergy in general; and on each allergic condition, including bronchial asthma, hay fever, allergic rhinitis, dermatoses, and allergy due to drugs, bacteria, fungi, and physical causes. Smaller sections deal with migraine and other headaches, and with allergy of the eyes and ears, heart, gastrointestinal and genitourinary tracts. A chapter is devoted to allergy in children and another to the technique of various types of skin tests. The book is especially

[1] THE PRECENTRAL MOTOR CORTEX. Edited by Paul C. Bucy. Urbana, Ill.: University of Illinois Press, 1944.

[2] ESSENTIALS OF ALLERGY. By Leo H. Criep, M.D. With a foreword by Robert A. Cooke, M.D. Philadelphia, London, and Montreal: J. B. Lippincott Co., 1945.

intended for medical students and general practitioners, and contains a great deal of very useful information (in a small compact volume). The print and style are very good, and the contents easily digestible. Sections on asthma and heart disease are especially good. The relation of surgery to allergic conditions is mentioned. The book is an excellent addition to the literature on allergy and is recommended. Those who want more information will consult larger volumes on specific subjects.

LEON UNGER.

THE anthology of the poems of 110 physicians of the ages, *Poet Physicians* by Mary Lou McDonough[1] with a brief biographical sketch preceding the illustrative sampling of each author, is a welcome cultural addition to medical history. Many of the 184 poems consist of but a few stanzas and cover a variety of topics common to the general vocational poet in but a fraction of a page.

This volume is individual in that it contains samples of poetical effusions by physicians on *medical* topics. Thus, it is quite different from the book entitled *Poetry and the Doctors* published in 1916 by Charles L. Dana which catalogued poetical works written by physicians. In this respect it also differs from Dr. Schlueter's paper in the *Bulletin of the Medical Library Association* (1939) which epitomizes in 16 pages medical contributors to all forms of literature.

American physician-poets are well represented in Mary McDonough's *Anthology*. Of these, Oliver Wendell Holmes' "The Morning Visit" is not only an outstanding poem, but a poem which carries instructive admonitions to every physician, young or old.

As this reviewer perused this volume, put out with the customary careful attention to all details of manufacturing and design which characterize the Thomas books, he was struck by the great number of poems pertaining to death, with such titles as "What Is It to Die," "Death," "The Anxious Dead," etc. On actual count such and similar titles constitute more than 5 per cent of the poetical offerings.

Only one typographical error was discovered, namely, the word "Osterisms" instead of "Oslerisms" on the jacket of the book.

This volume would no doubt be highly cherished by any physician as a gift from a colleague or from a grateful patient.

ARNO B. LUCKHARDT.

[1] POET PHYSICIANS; AN ANTHOLOGY OF MEDICAL POETRY WRITTEN BY PHYSICIANS. Compiled by Mary Lou McDonough. Springfield, Ill.: Charles C. Thomas, 1945.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgement must be regarded as sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

FRANCOIS MAGENDIE; PIONEER IN EXPERIMENTAL PHYSIOLOGY & SCIENTIFIC MEDICINE IN XIX CENTURY FRANCE. By J. M. D. Olmsted. New York: Schuman's, 1945.

ESSENTIALS OF BODY MECHANICS IN HEALTH AND DISEASE. By Joel E. Goldthwaite, M.D., F.A.C.S., LL.D., Lloyd T. Brown, M.D., F.A.C.S., Loring T. Swaim, M.D., and John G. Kuhns, M.D., F.A.C.S. 4th ed. Philadelphia: J. B. Lippincott Co., 1945.

AUTOBIOGRAPHY OF SCIENCE. Edited by Forest Ray Moulton, M.D. and Justus J. Schifferes. New York: Doubleday Doran, Inc., 1945.

AN INDEX OF DIFFERENTIAL DIAGNOSIS OF MAIN SYMPTOMS. By various writers. Edited by Herbert French, C.V.O., C.B.E., M.A., M.D.(Oxon.), F.R.C.P. 6th ed. Baltimore: The Williams & Wilkins Co., 1945.

THE HISTORY OF SURGICAL ANESTHESIA. By Thomas E. Keys. New York: Schuman's, 1945.

RYPINS' MEDICAL LICENSURE EXAMINATIONS. Edited by Walter L. Bierring, M.D., F.A.C.P., M.R.C.P., Edin. (Hon.) With the Collaboration of a Review Panel. 5th ed. Philadelphia: J. B. Lippincott Co., 1945.

MEN UNDER STRESS. By Roy R. Grinker, Lt. Col., M.C. and John P. Spiegel, Major, M.C. Philadelphia: The Blakiston Co., 1945.

CLINICAL TRAUMATIC SURGERY. By John. J. Moorhead, B.S., M.D., D.Sc., F.A.C.A. (D.S.M.). Philadelphia: W. B. Saunders Co., 1945.

BONE-GRAFTING; IN THE TREATMENT OF FRACTURES. By J. R. Armstrong, M.D., M.Ch., F.R.C.S. Baltimore: The Williams & Wilkins Co., 1945.

CANCER OF THE COLON AND RECTUM; ITS DIAGNOSIS AND TREATMENT. By Fred W. Rankin, B.A., M.A., M.D., LL.D., Sc.D., F.A.C.S., and A. Stephens Graham, M.D., M.S. (in Surgery), F.A.C.S. Springfield: Charles C. Thomas, 1945.

Photograph of abdominal cavity of rabbit three days after xylene was liberally applied to the peritoneal surface of stomach, intestines, and abdominal wall. Shows entire absence of any tissue irritation—no free peritoneal fluid, no dilatation of superficial vessels, no adhesions.

The Fallacy of Surgical Gut (Catgut) Tubing Fluid as a Tissue Irritant.—John O. Bower